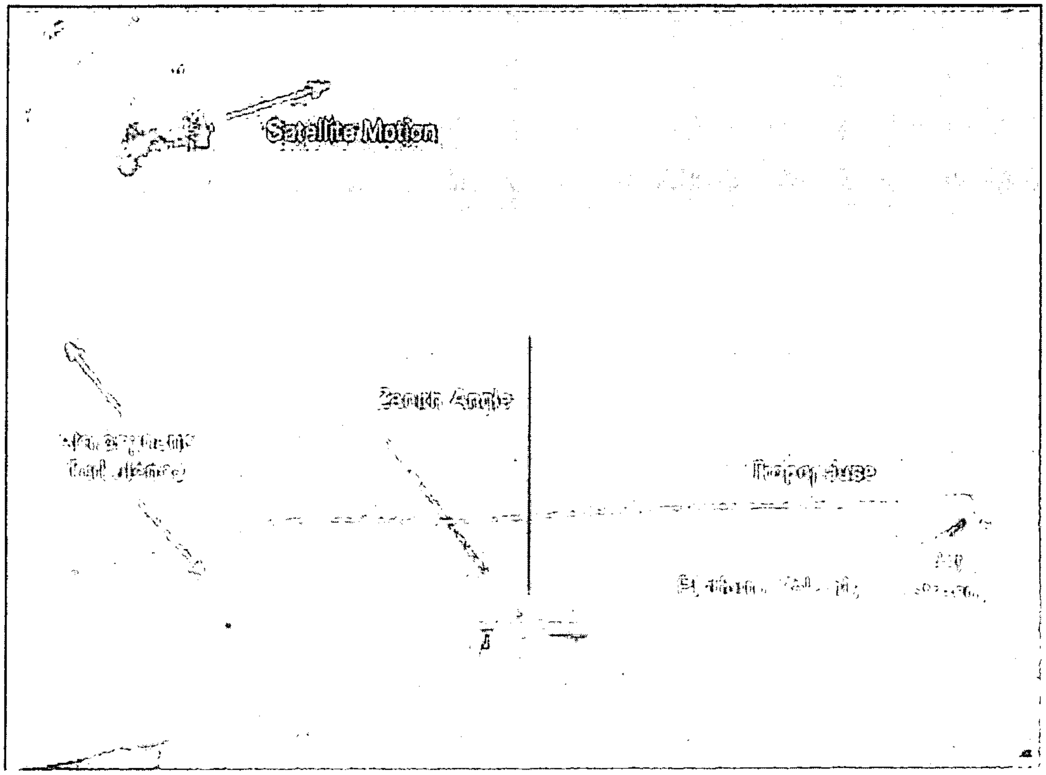
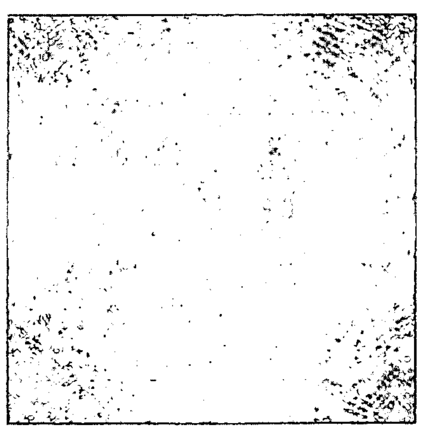


Platform Parameters

FIG. 1A

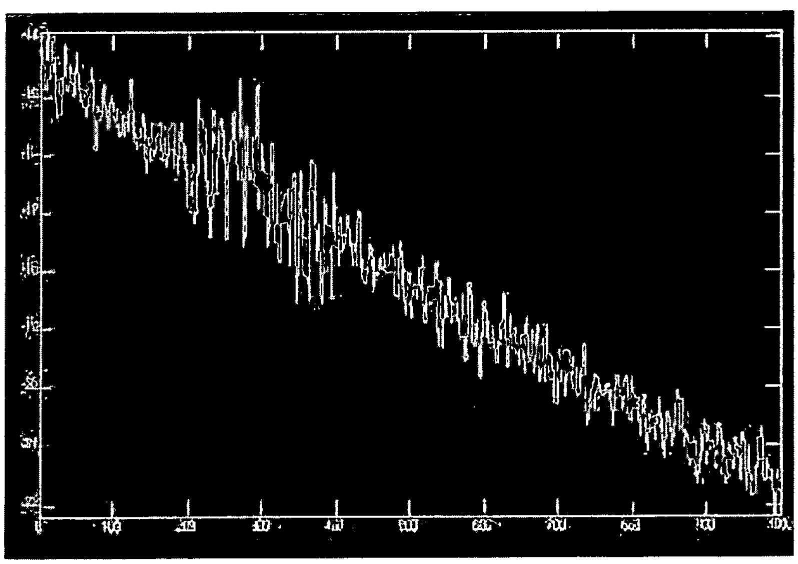


Phase Map Through Turbulance

FIG. 1B

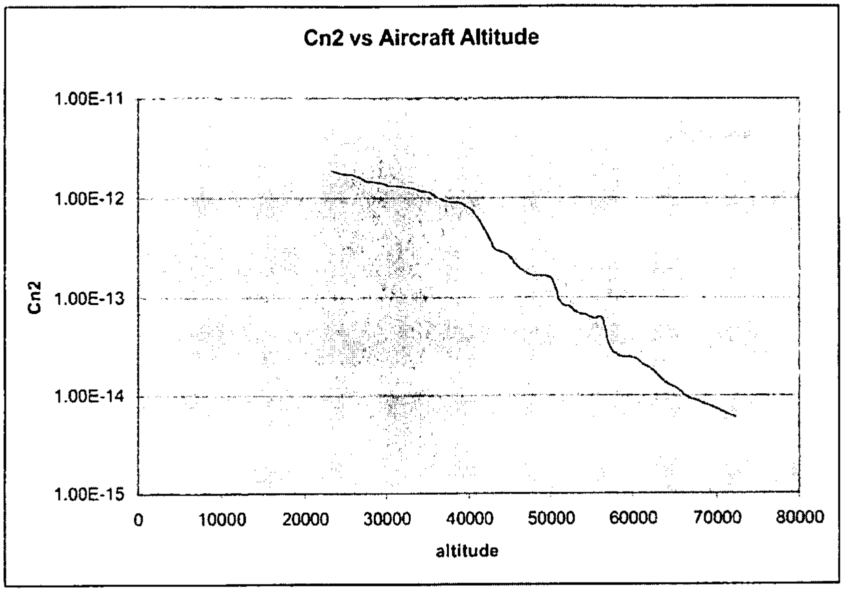
Time Sequence of Beam Distribution at Satellite
(bar represents 10m at 1000km)

FIG. 1C



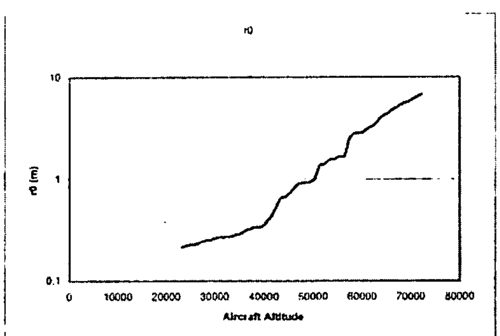
Simulated C_n^2 profile

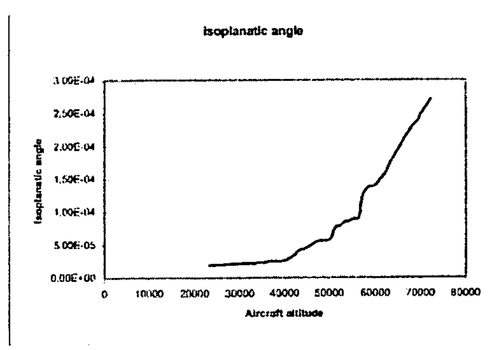
FIG. 1D



Integrated C_n^2 versus aircraft altitude in feet

FIG. 1E

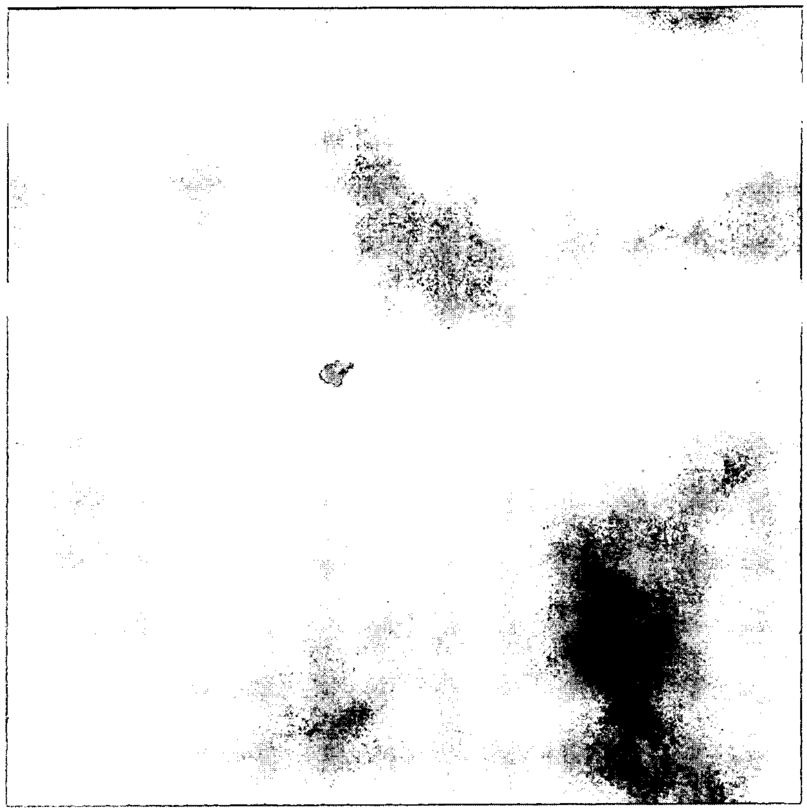




Atmospheric coherence parameters versus aircraft altitude

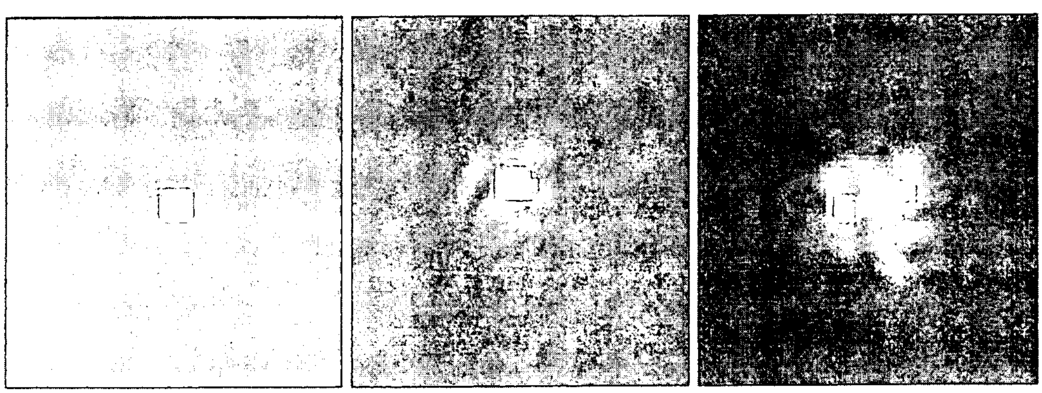
FIG. 1F1

FIG. 1F2



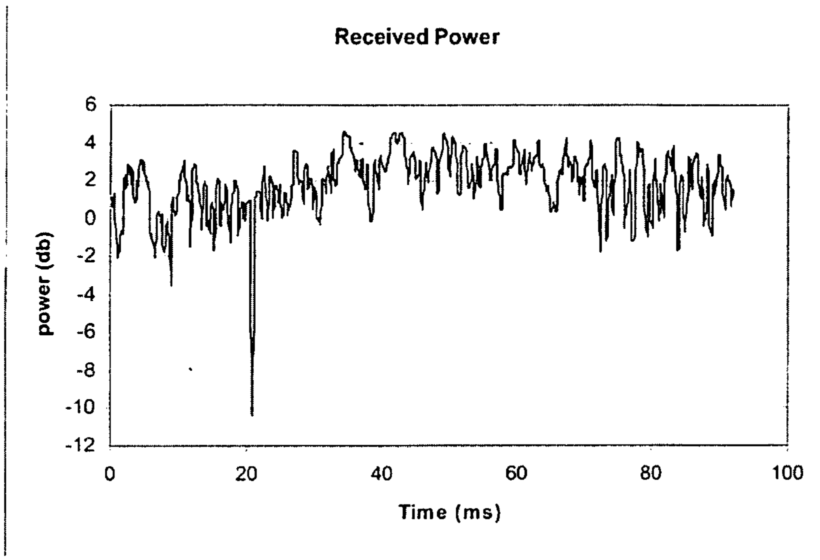
Simulated turbulence induced phase error

FIG. 1G



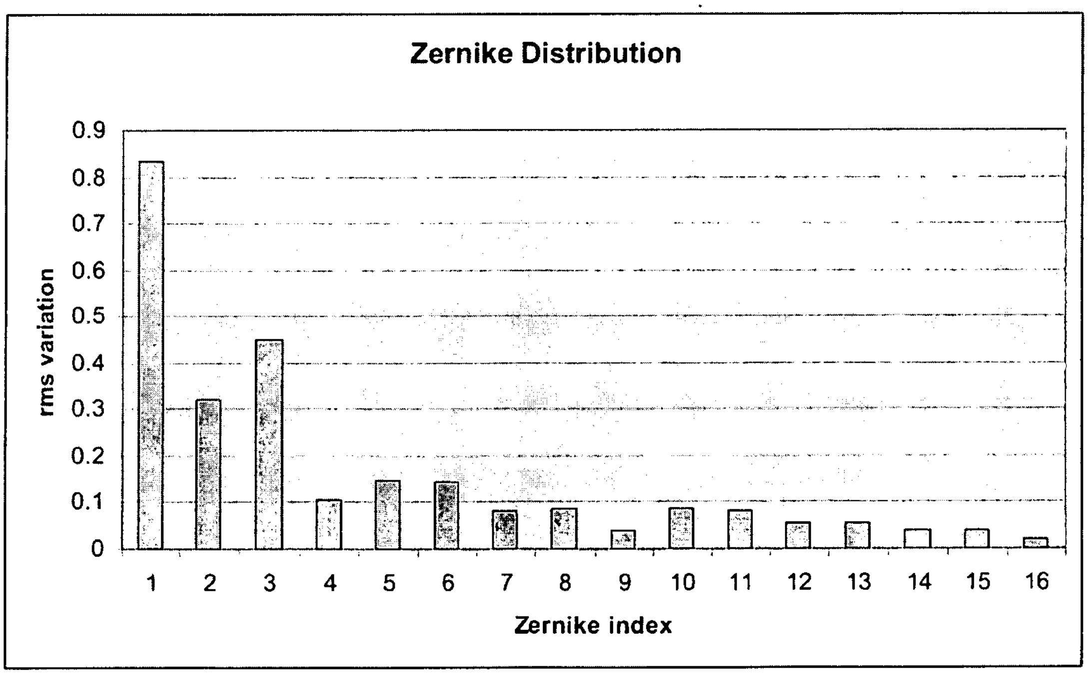
Diffraction limited beam profile (left) and typical beam profiles at satellite

FIG. 1H



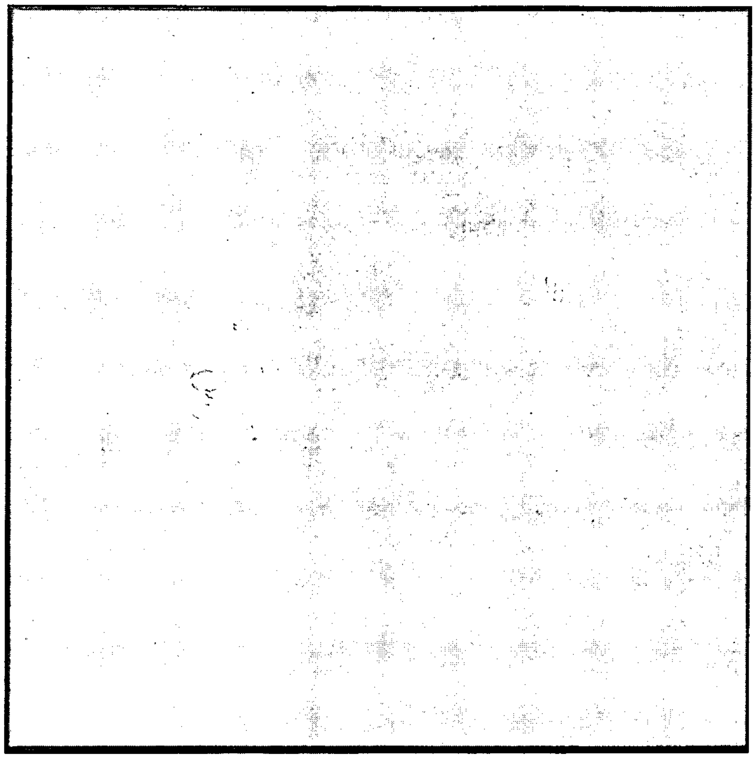
Time Series of Received Power

FIG. 1I



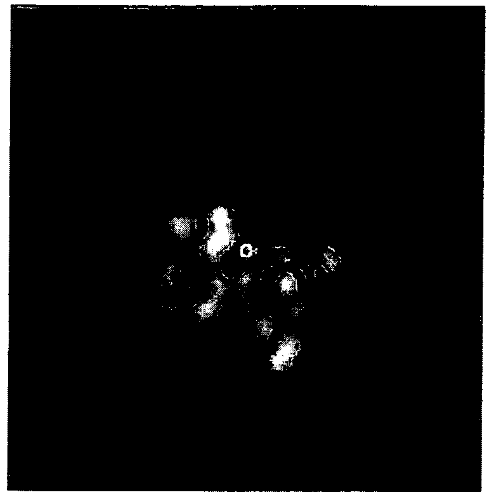
Temporal Variation in Lowest 15 Zernike terms

FIG. 1J



Intensity distribution at receiver aperture

FIG. 1K



Spot during a deep fade event

FIG. 1M

Typical calculated spot at detector plane

FIG. 1L

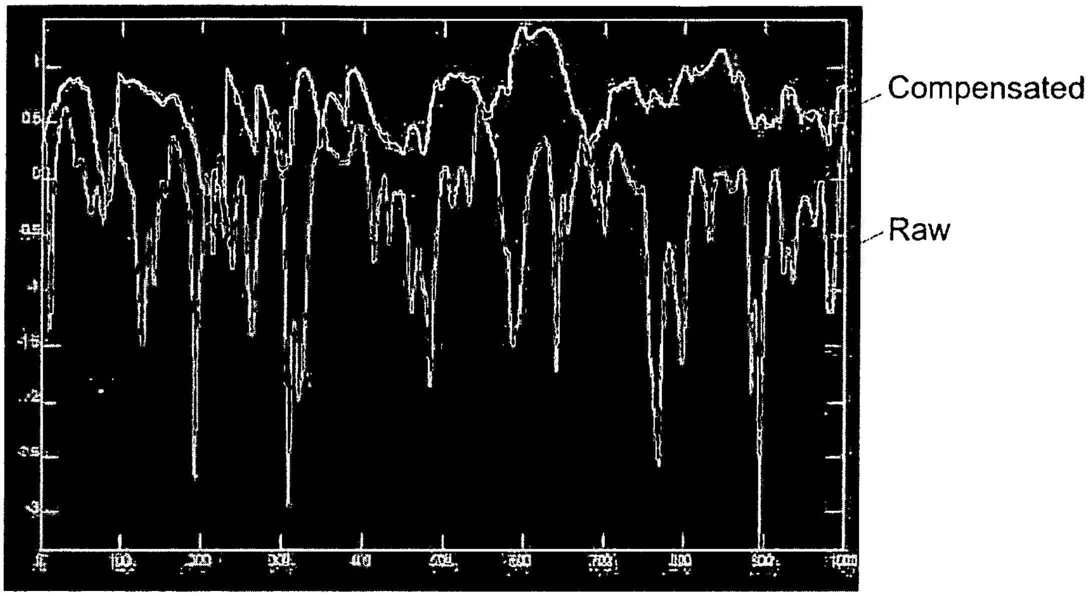


FIG. 1N

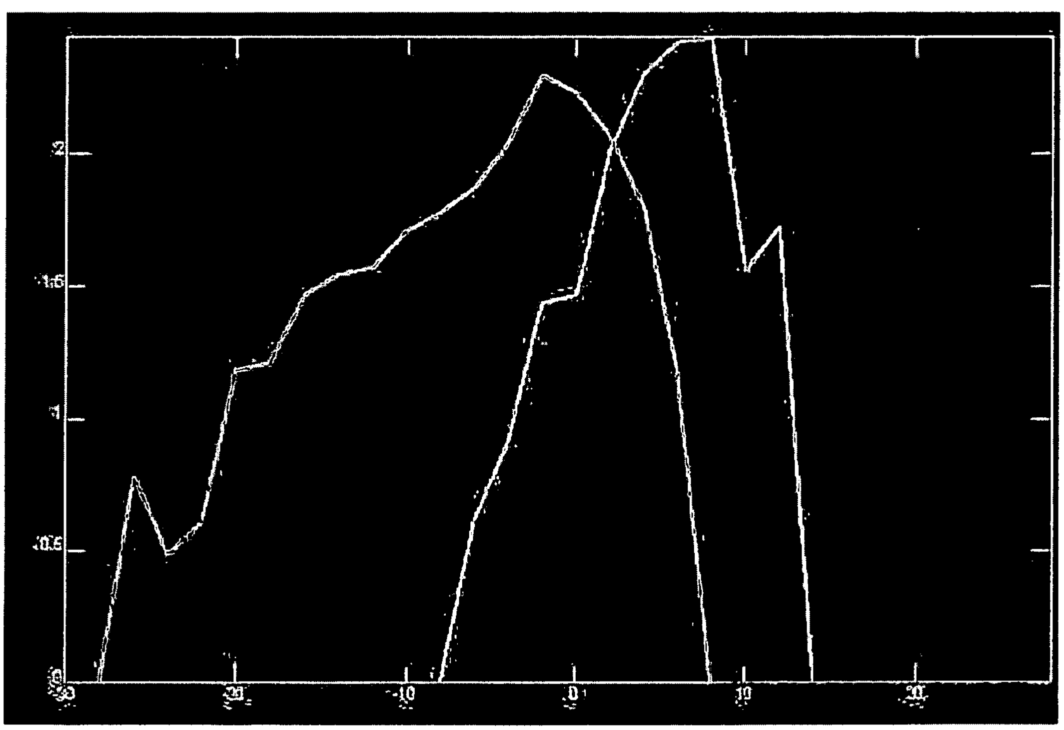


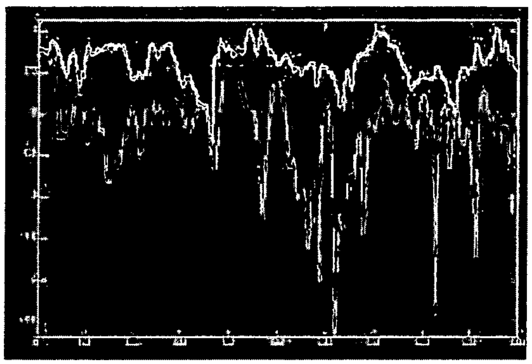
FIG. 1O

Blur spots formed by aperture with 0.2, 0.5, and 1.0 wave phase steps

FIG. 1P

Modulation of a speckle pattern by a phase step

FIG. 1Q



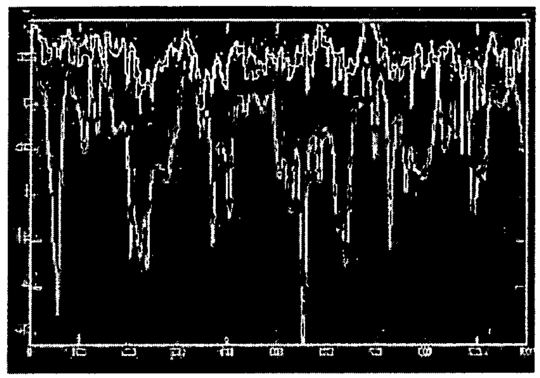
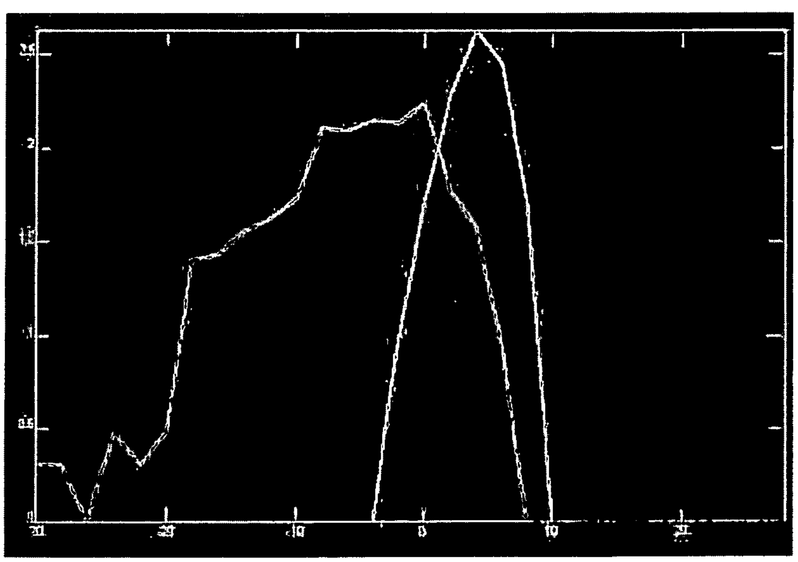


FIG. 1R1

FIG. 1R2

Log intensity vs. iteration number.
Left, 2X2 phase modulator; right, 4X4 phase modulator.



PDF for the data in Fig. 9K2

FIG. 1S

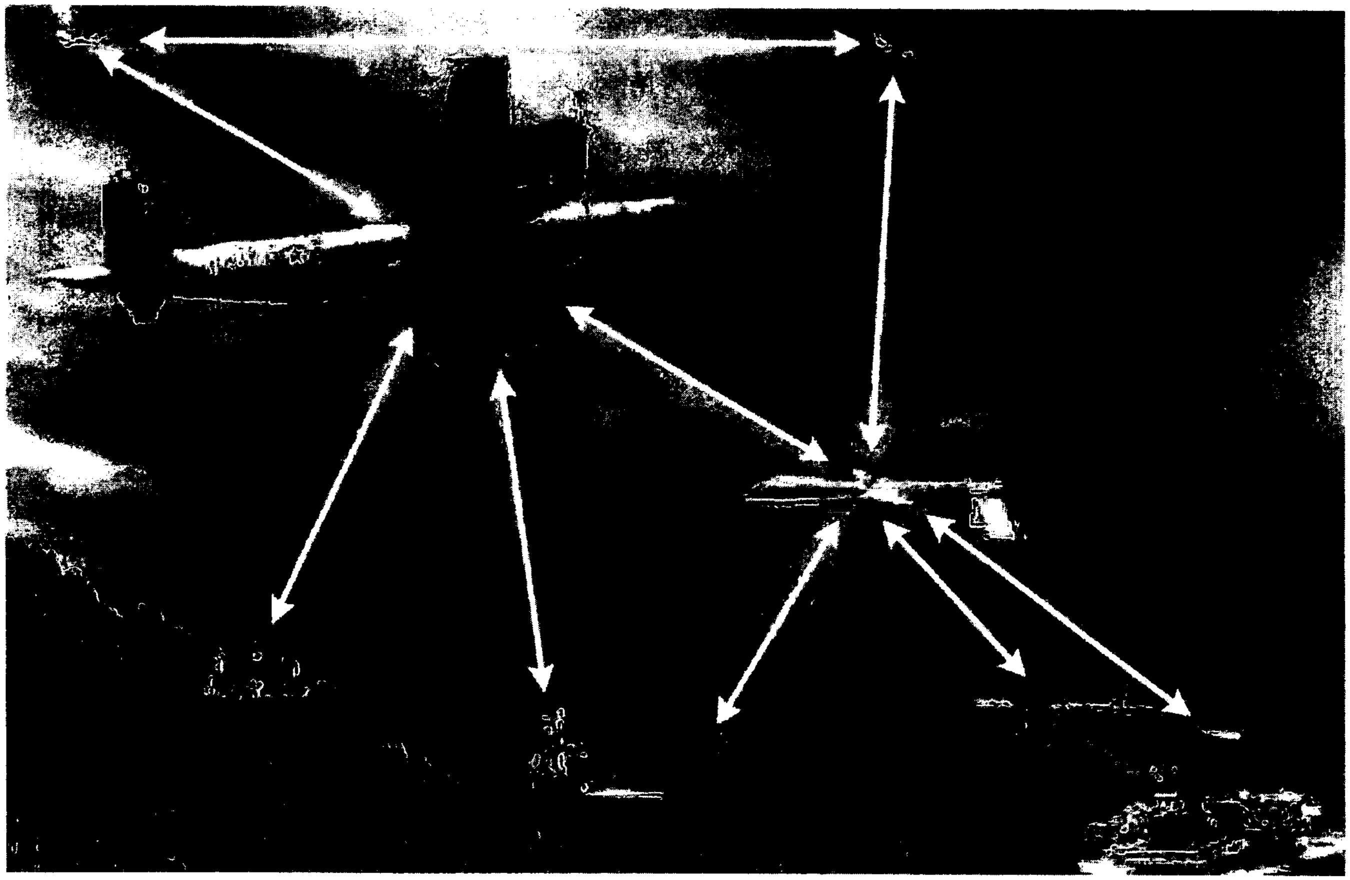


FIG. 2A

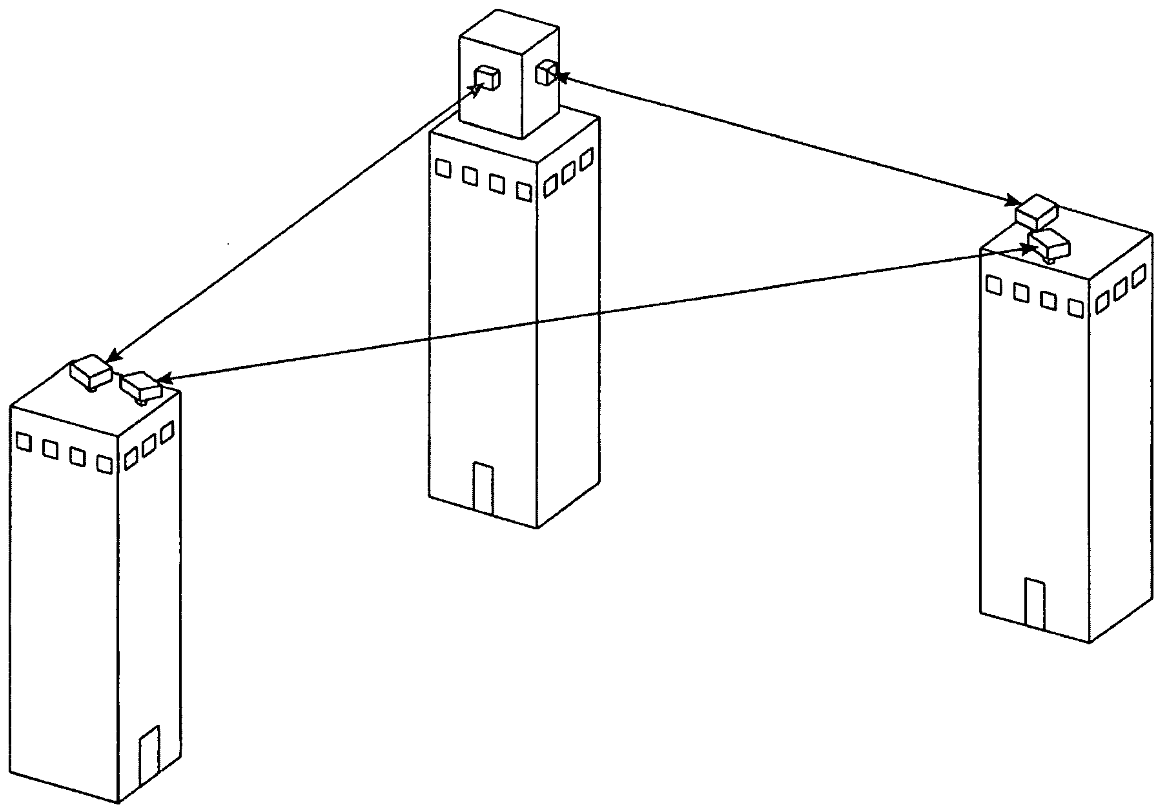


FIG. 2B

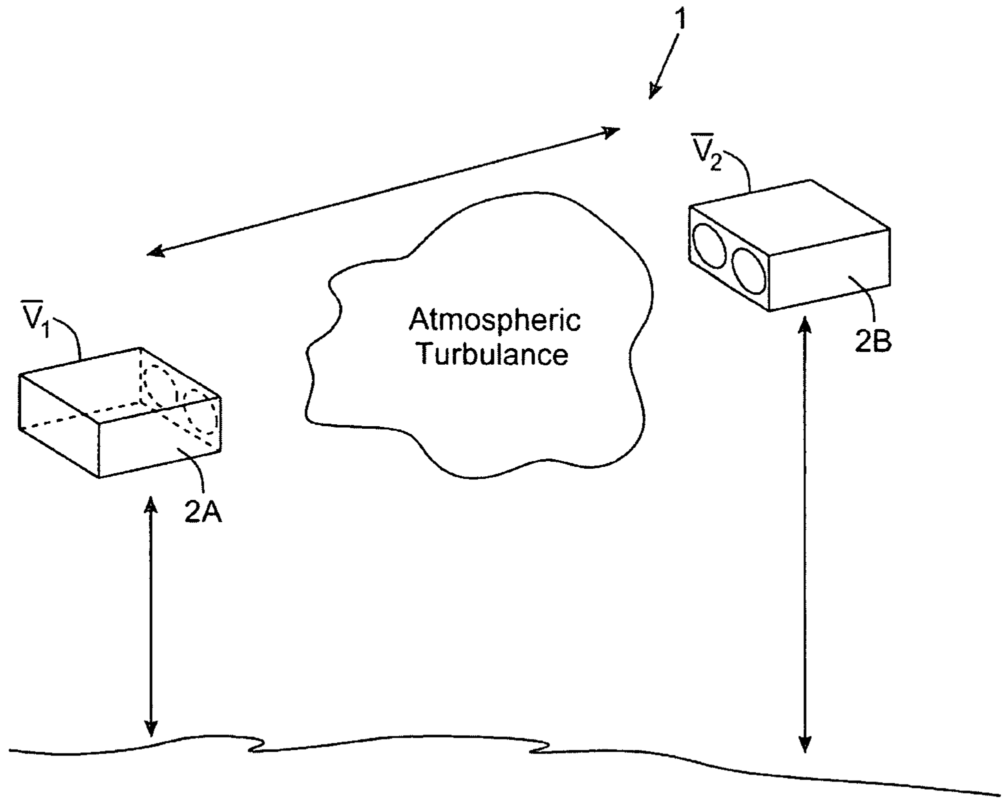


FIG. 3A

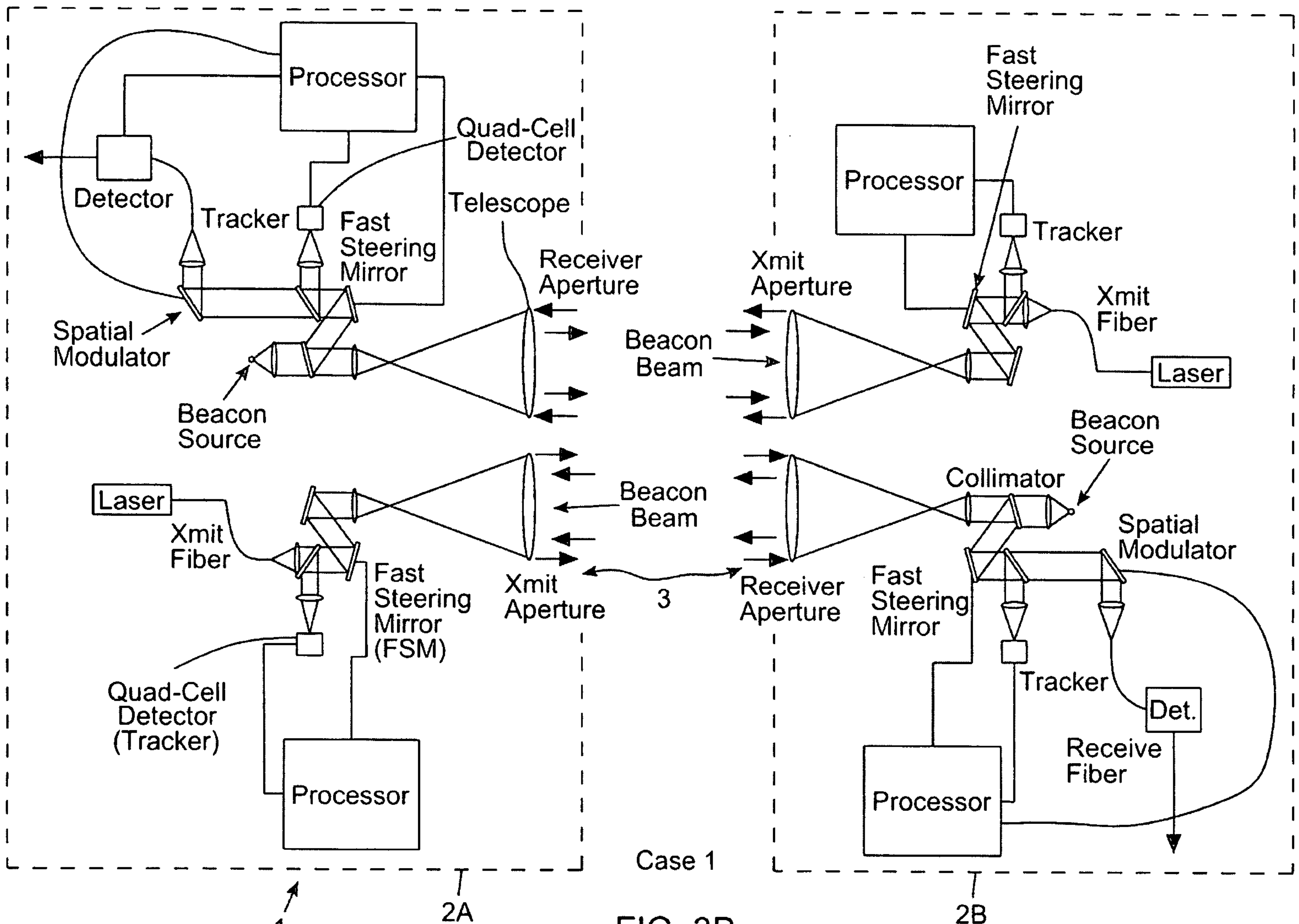

Processor
Quad-Cell
Detector
Detector
Tracker
Fast
Steering
Mirror
Telescope
Receiver
Aperture
Spatial
Modulator
Beacon
Source
Laser
Xmit
Fiber
Beacon
Beam
Fast
Steering
Mirror
(FSM)
Xmit
Aperture
Quad-Cell
Detector
(Tracker)
Processor
3
Fast
Steering
Mirror
Processor
Tracker
Xmit
Aperture
Xmit
Fiber
Beacon
Beam
Laser
Beacon
Source
Collimator
Spatial
Modulator
Receiver
Aperture
Fast
Steering
Mirror
Tracker
Det.
Receive
Fiber
Processor
Case 1
1
2A
2B

FIG. 3B

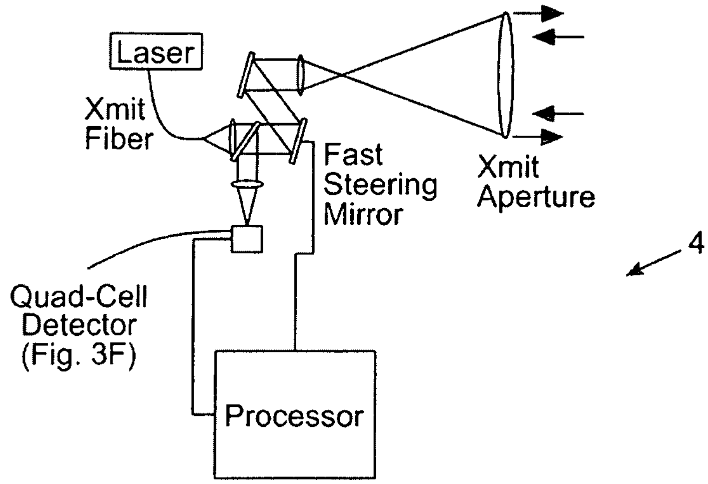

Laser
Xmit
Fiber
Fast
Steering
Mirror
Xmit
Aperture
4
Quad-Cell
Detector
(Fig. 3F)
Processor

FIG. 3C

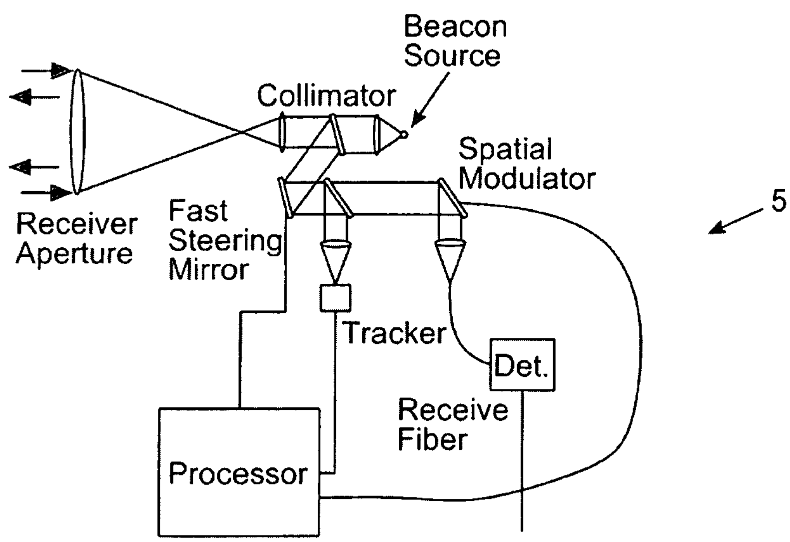
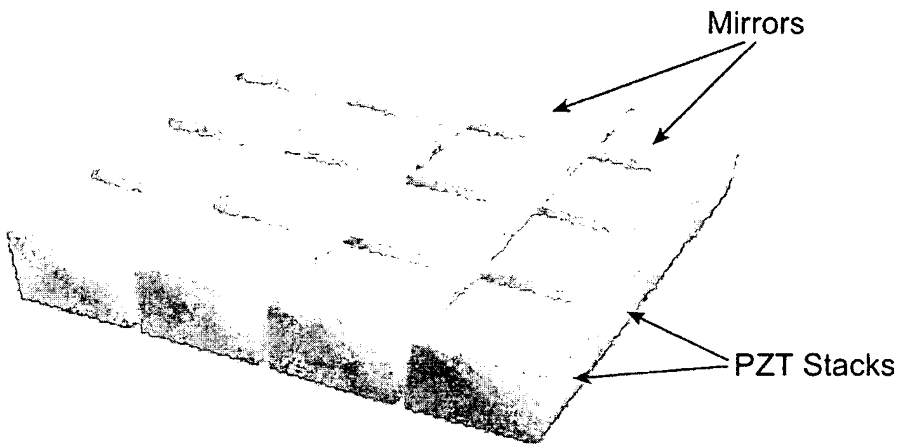
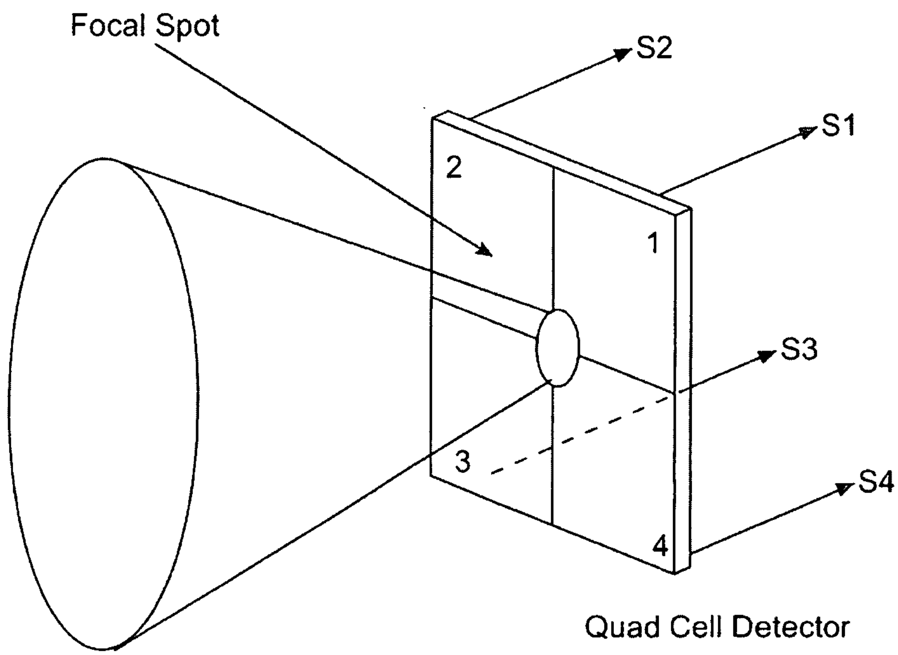

Beacon
Source
Collimator
Spatial
Modulator
5
Receiver
Aperture
Fast
Steering
Mirror
Tracker
Det.
Receive
Fiber
Processor

FIG. 3D



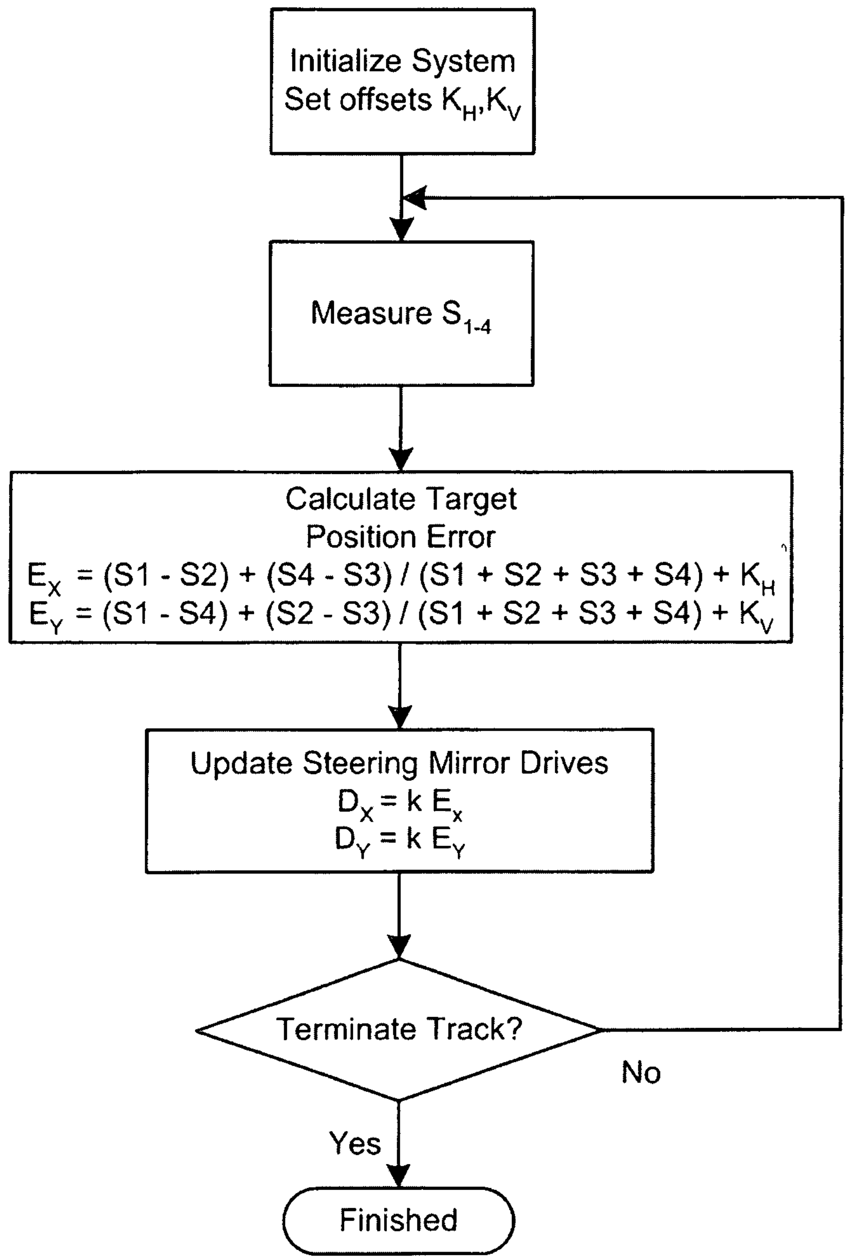
Mirrors
PZT Stacks

FIG. 3E



Focal Spot
S2
S1
2
1
S3
3
S4
4
Quad Cell Detector

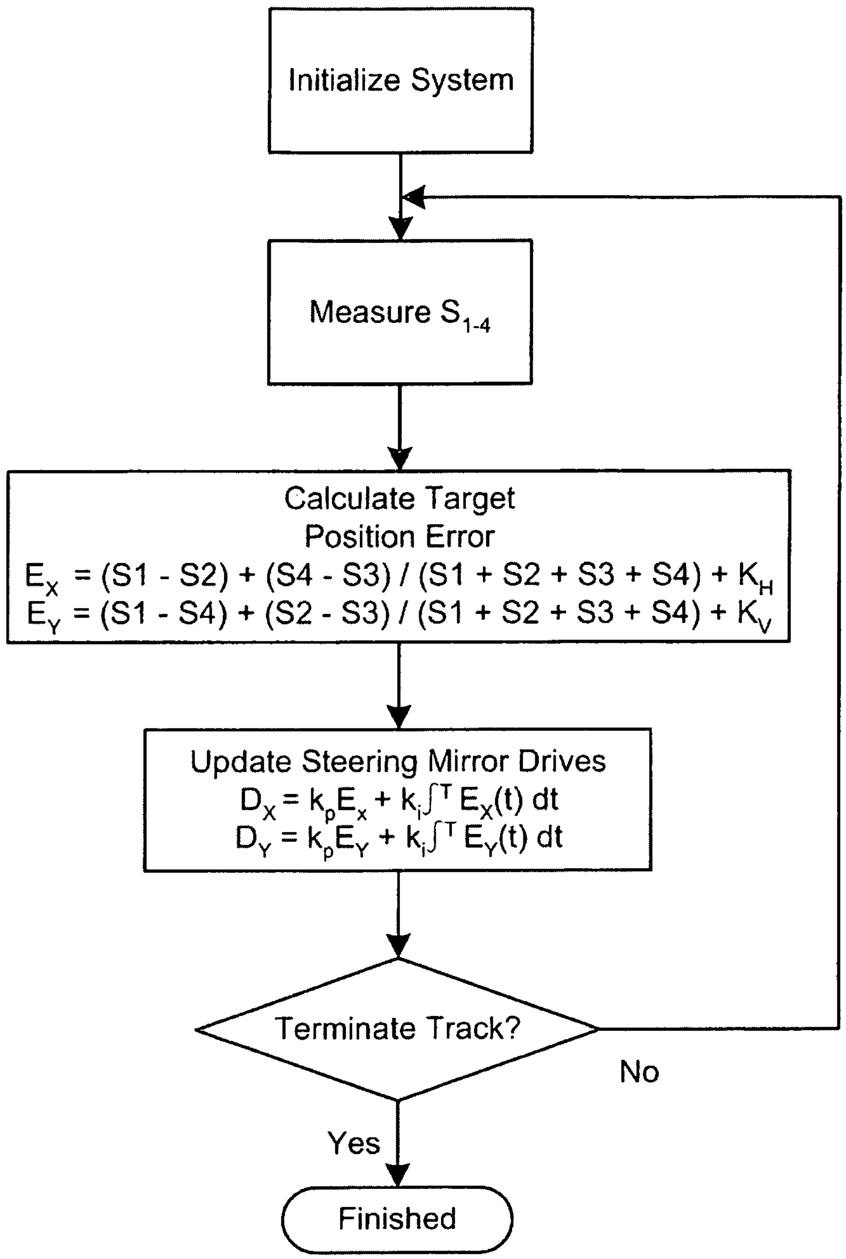
FIG. 3F



Proportional Control

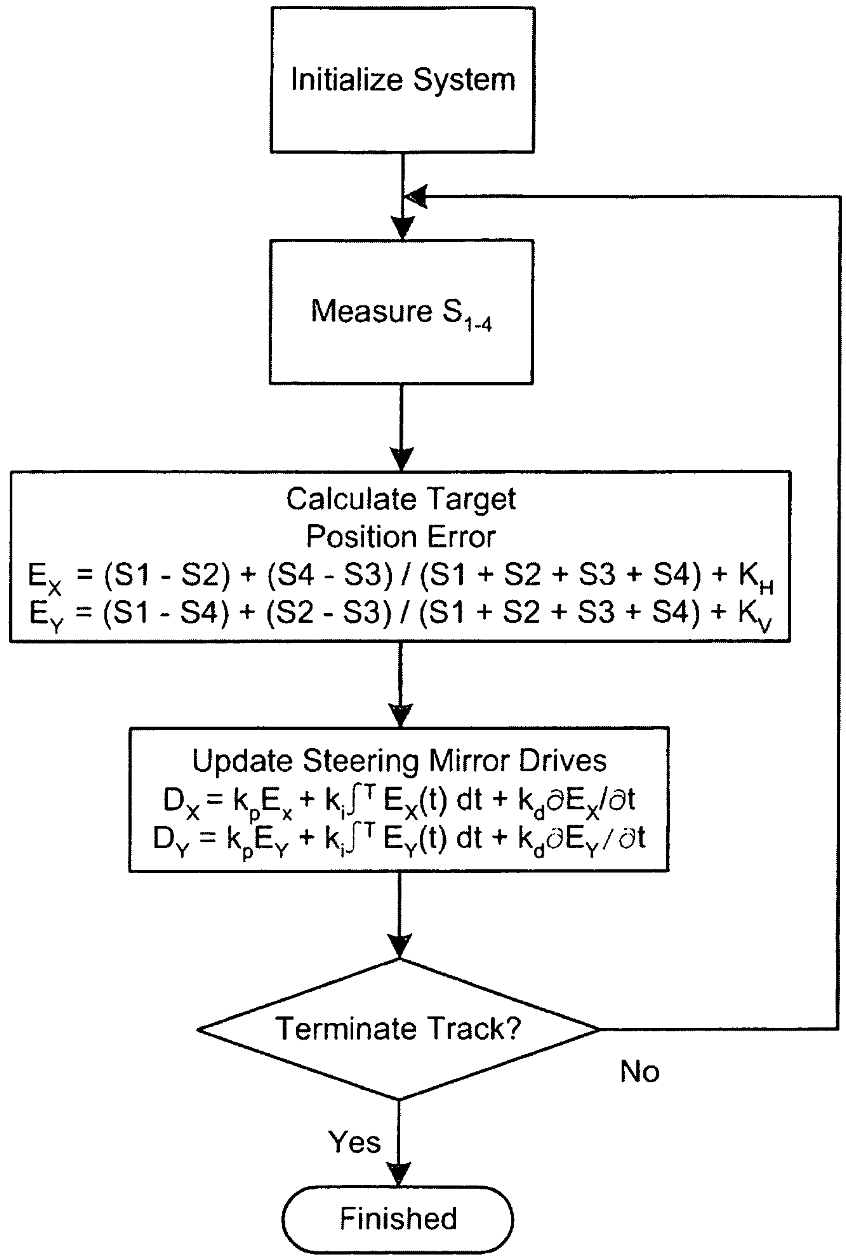
Transmitter

FIG. 4A



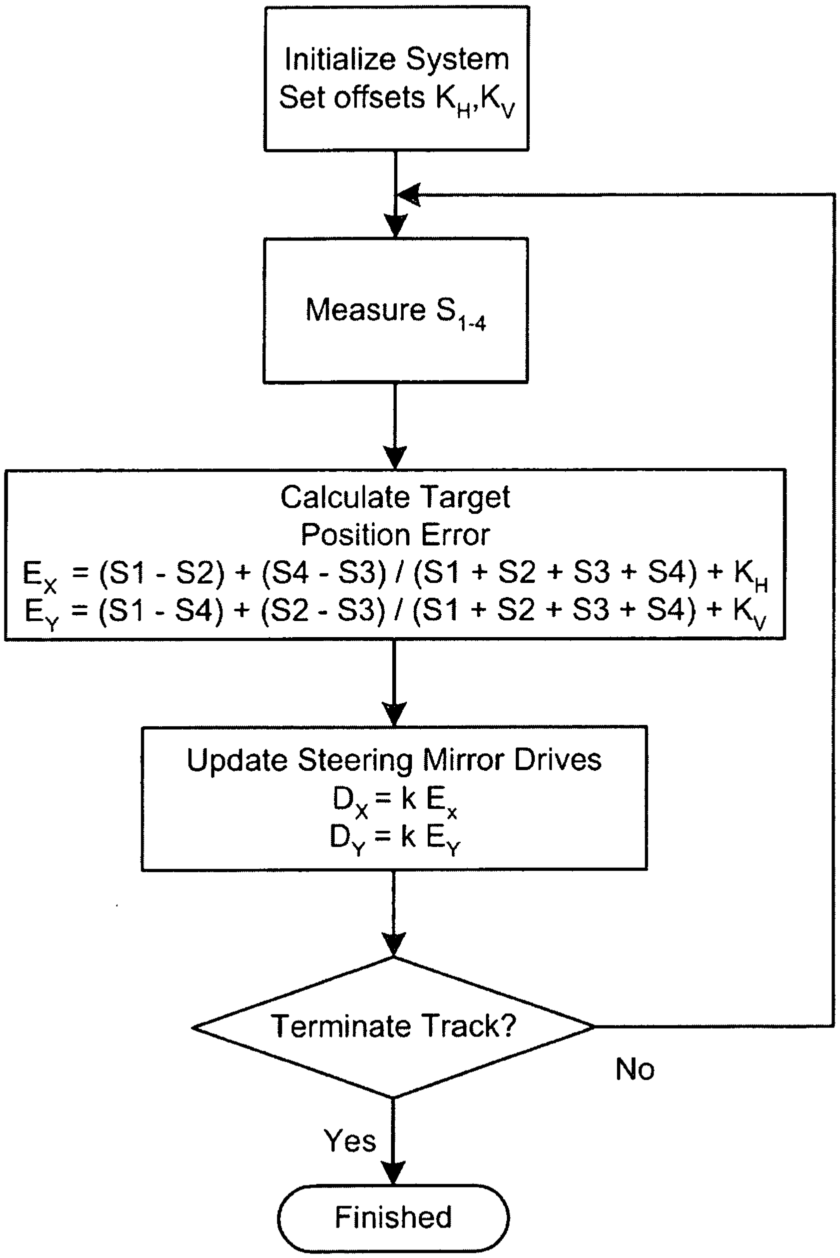
Proportional Plus Integral Control

FIG. 4B



Proportional Plus Integral Control Plus Derivative

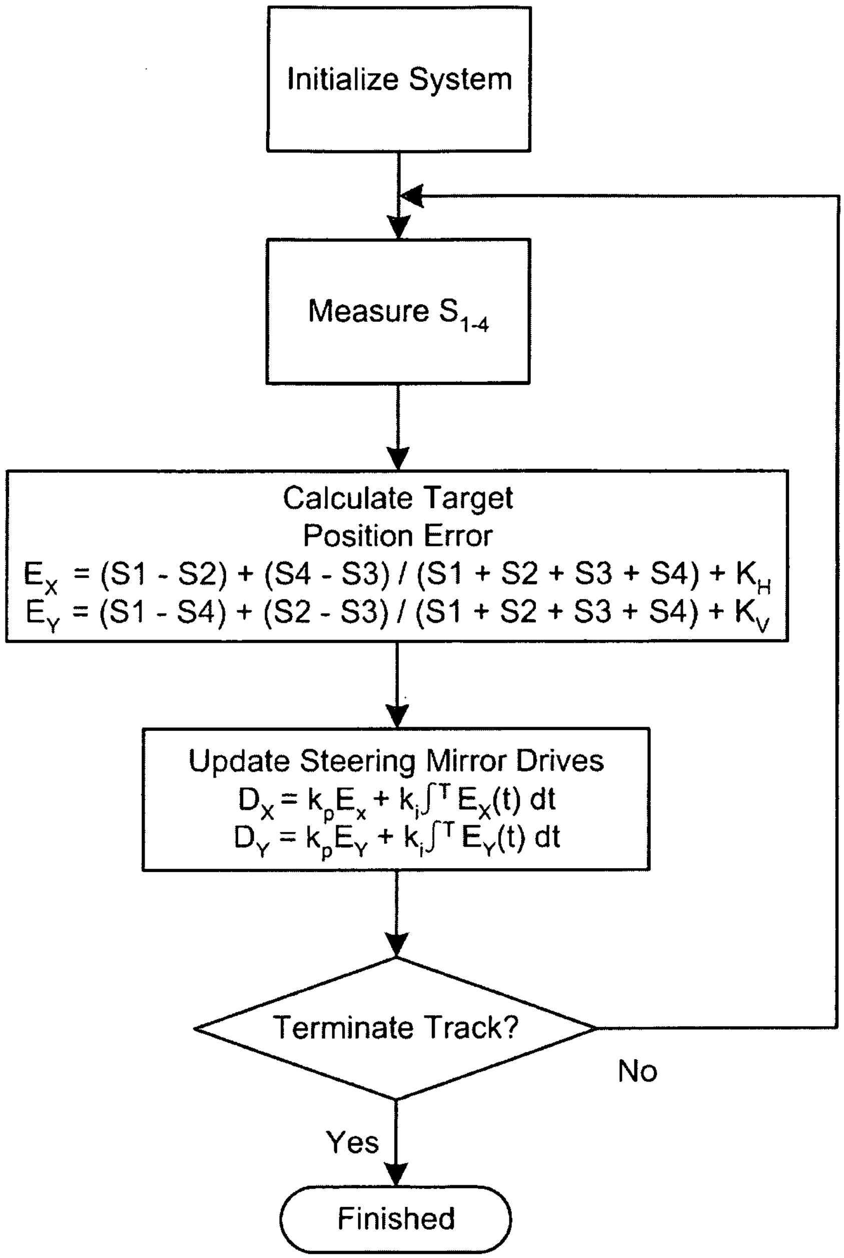
FIG. 4C



Proportional Control

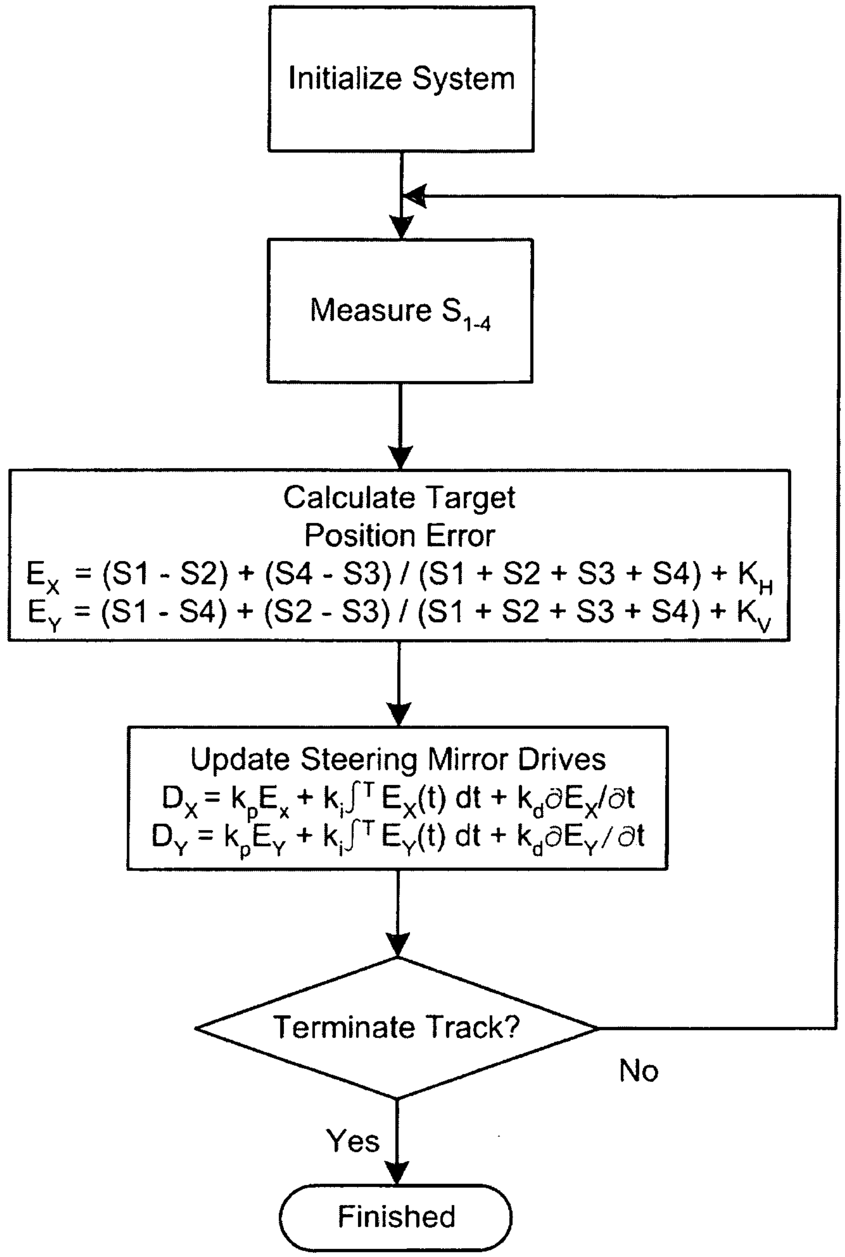
Receiver

FIG. 4D



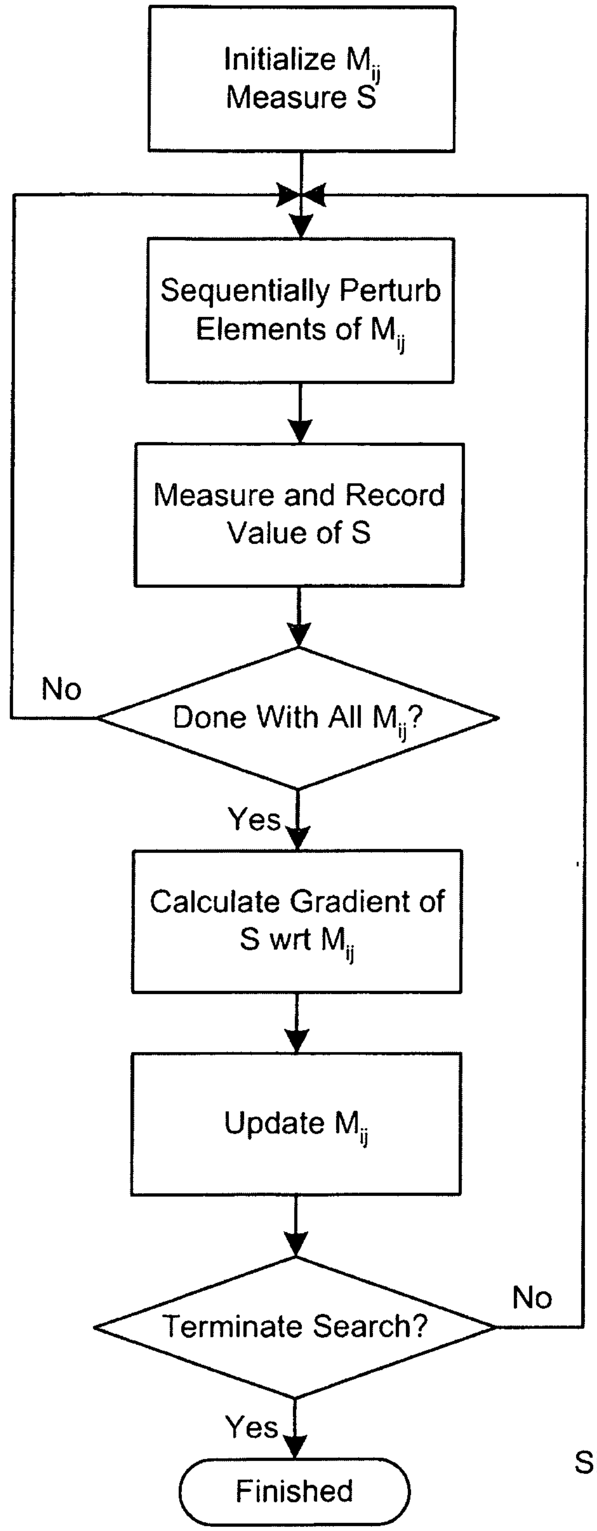
Proportional Plus Integral Control

FIG. 4E



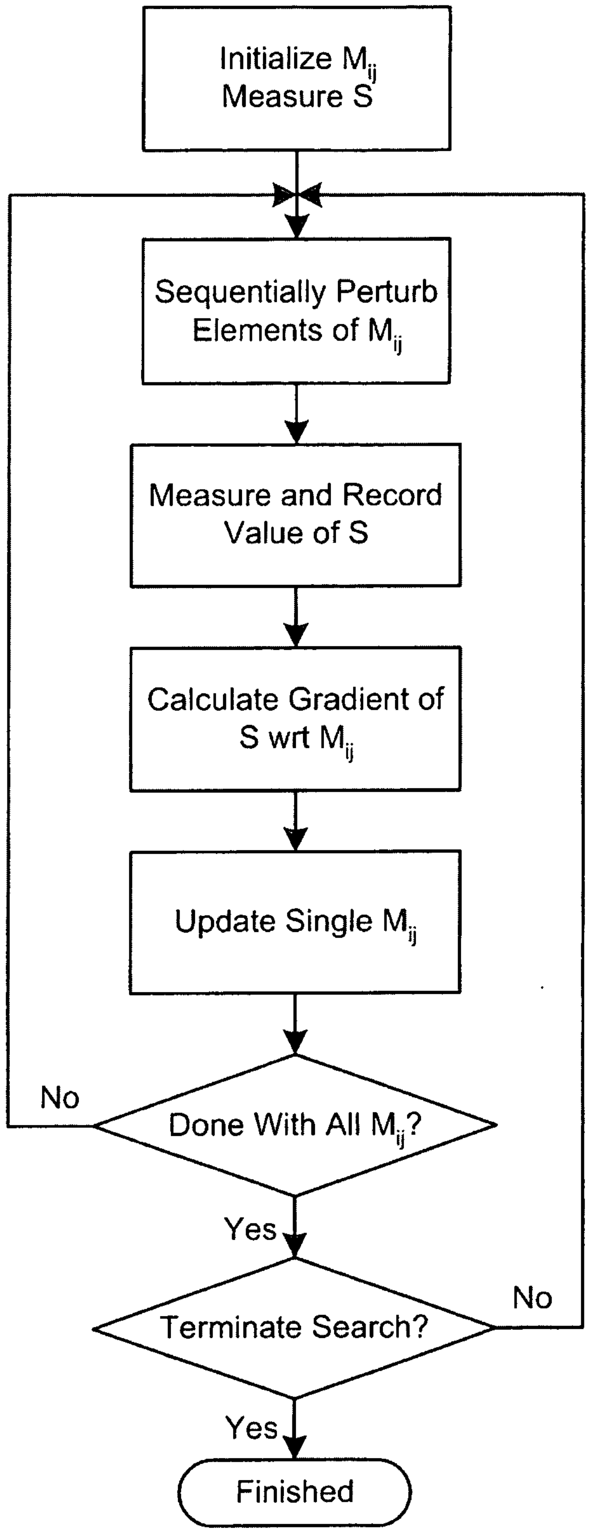
Proportional Plus Integral Control Plus Derivative

FIG. 4F



SPM Control Signal Generation Algorithm

FIG. 5A



Initialize M_{ij}
Measure S
Sequentially Perturb Elements of M_{ij}
Measure and Record Value of S
Calculate Gradient of S wrt M_{ij}
Update Single M_{ij}
No
Done With All M_{ij}?
Yes
Terminate Search?
No
Yes
Finished

FIG. 5B

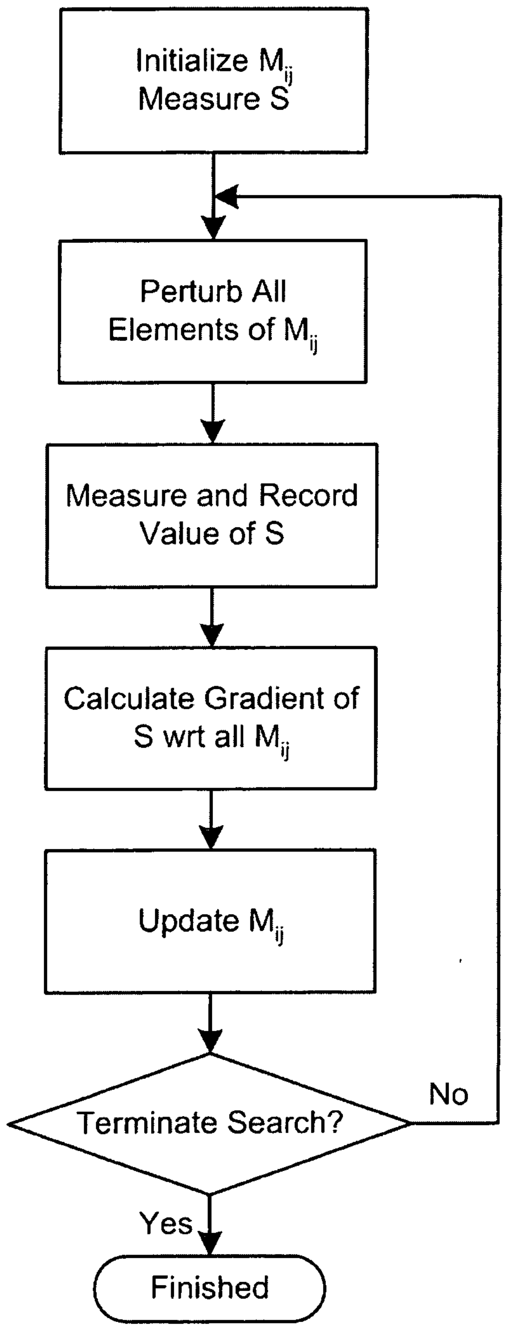
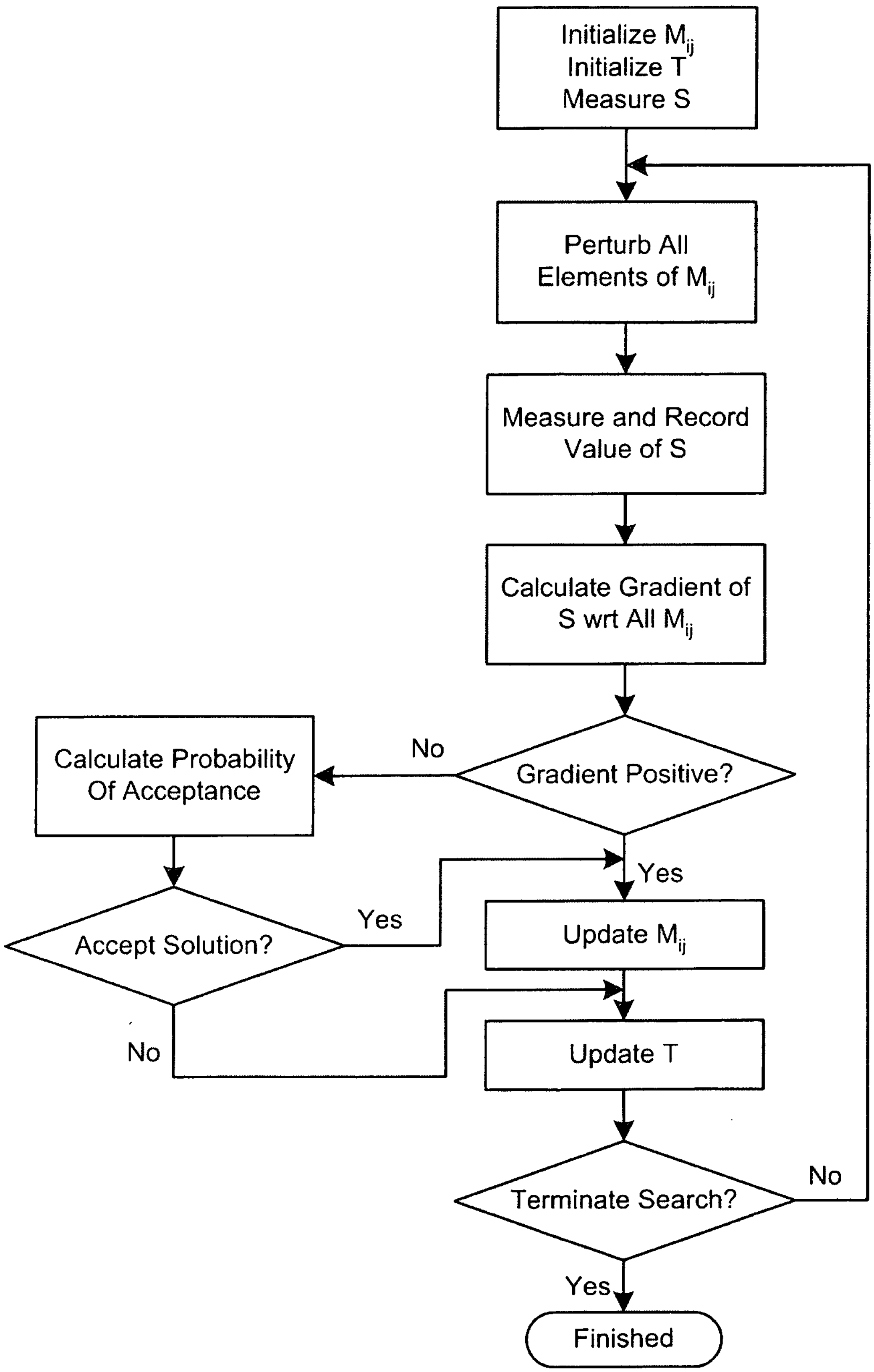

Initialize M_{ij}
Measure S
Perturb All Elements of M_{ij}
Measure and Record Value of S
Calculate Gradient of S wrt all M_{ij}
Update M_{ij}
Terminate Search?
No
Yes
Finished

FIG. 5C



Initialize M_{ij}
Initialize T
Measure S
Perturb All Elements of M_{ij}
Measure and Record Value of S
Calculate Gradient of S wrt All M_{ij}
Gradient Positive?
No
Yes
Calculate Probability Of Acceptance
Accept Solution?
Yes
No
Update M_{ij}
Update T
Terminate Search?
No
Yes
Finished

FIG. 5D

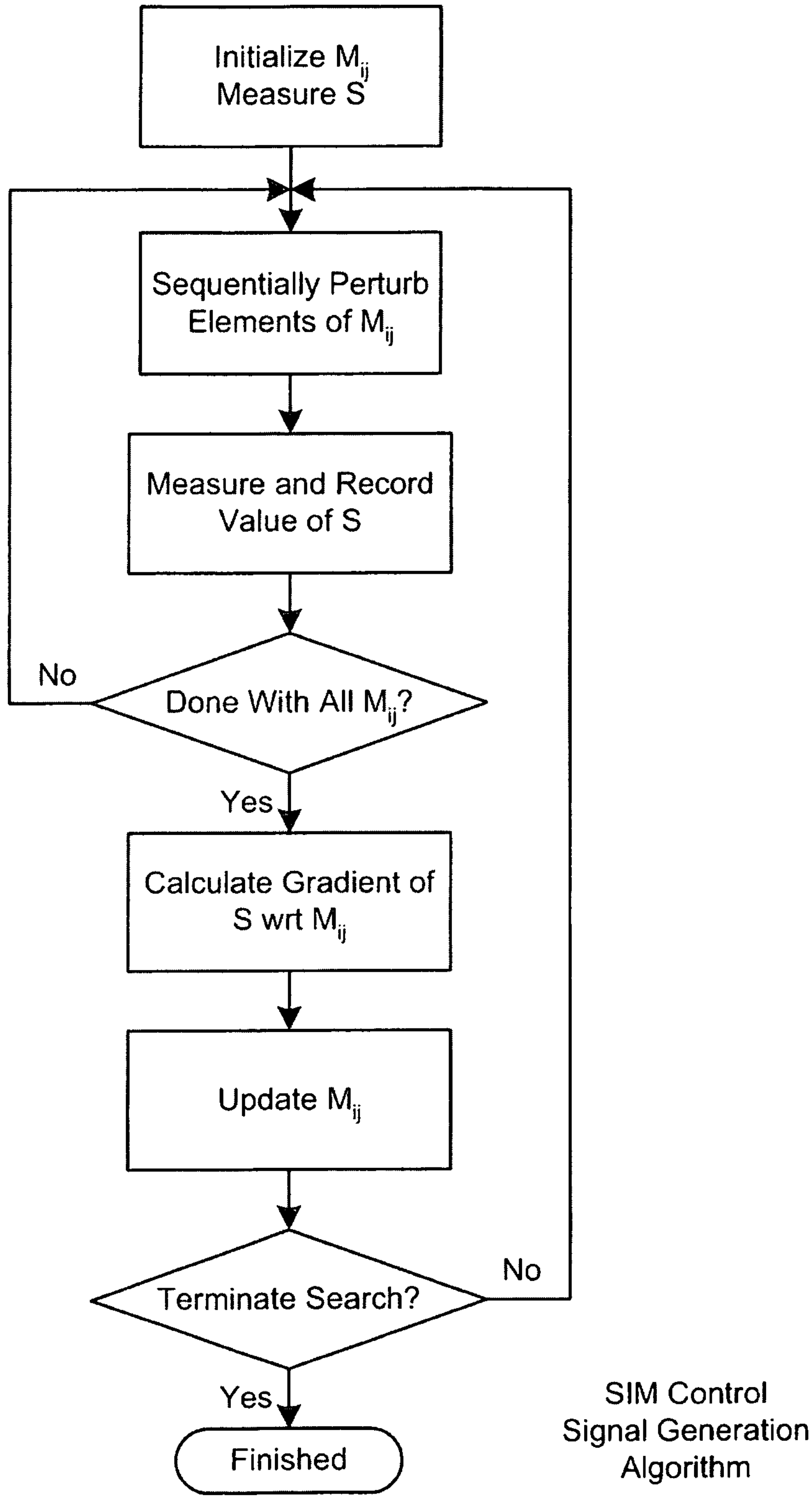

Initialize M_{ij}
Measure S
Sequentially Perturb Elements of M_{ij}
Measure and Record Value of S
Done With All M_{ij}?
No
Yes
Calculate Gradient of S wrt M_{ij}
Update M_{ij}
Terminate Search?
No
Yes
Finished
SIM Control Signal Generation Algorithm

FIG. 6A

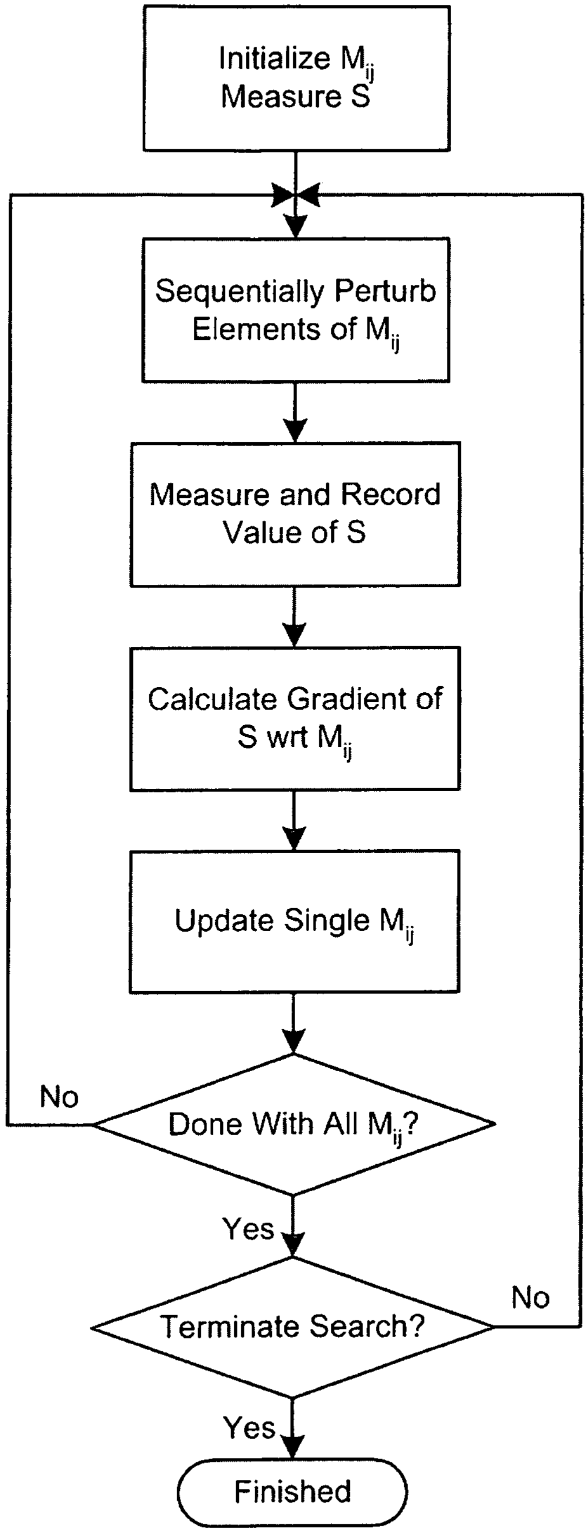

Initialize M_{ij}
Measure S
Sequentially Perturb Elements of M_{ij}
Measure and Record Value of S
Calculate Gradient of S wrt M_{ij}
Update Single M_{ij}
No
Done With All M_{ij}?
Yes
No
Terminate Search?
Yes
Finished

FIG. 6B

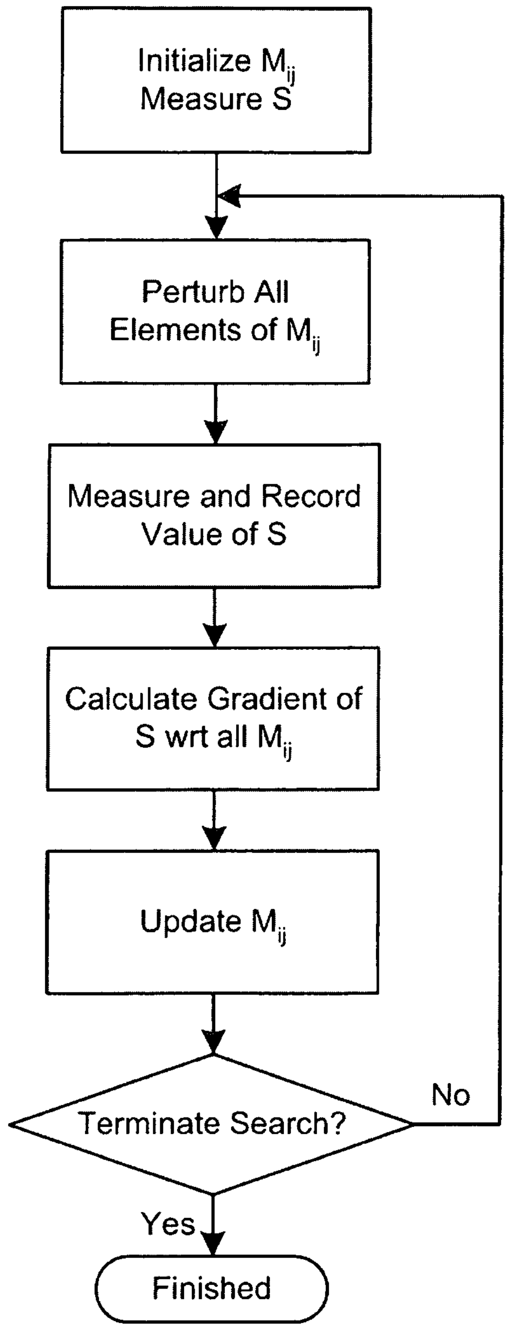

Initialize M_{ij}
Measure S
Perturb All Elements of M_{ij}
Measure and Record Value of S
Calculate Gradient of S wrt all M_{ij}
Update M_{ij}
Terminate Search?
No
Yes
Finished

FIG. 6C

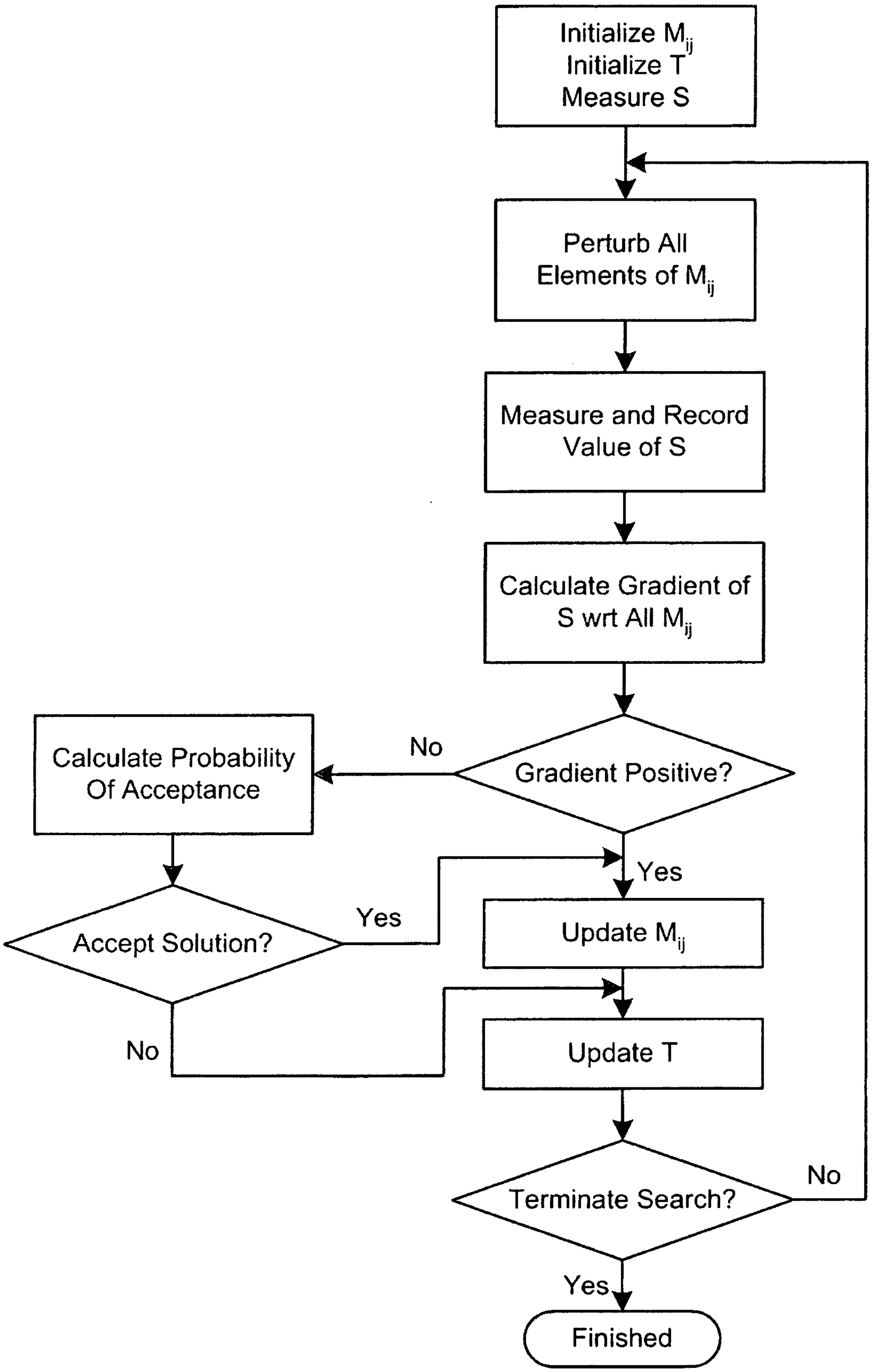

Initialize M_{ij}
Initialize T
Measure S
Perturb All Elements of M_{ij}
Measure and Record Value of S
Calculate Gradient of S wrt All M_{ij}
Gradient Positive?
No
Calculate Probability Of Acceptance
Accept Solution?
Yes
No
Yes
Update M_{ij}
Update T
Terminate Search?
No
Yes
Finished

FIG. 6D

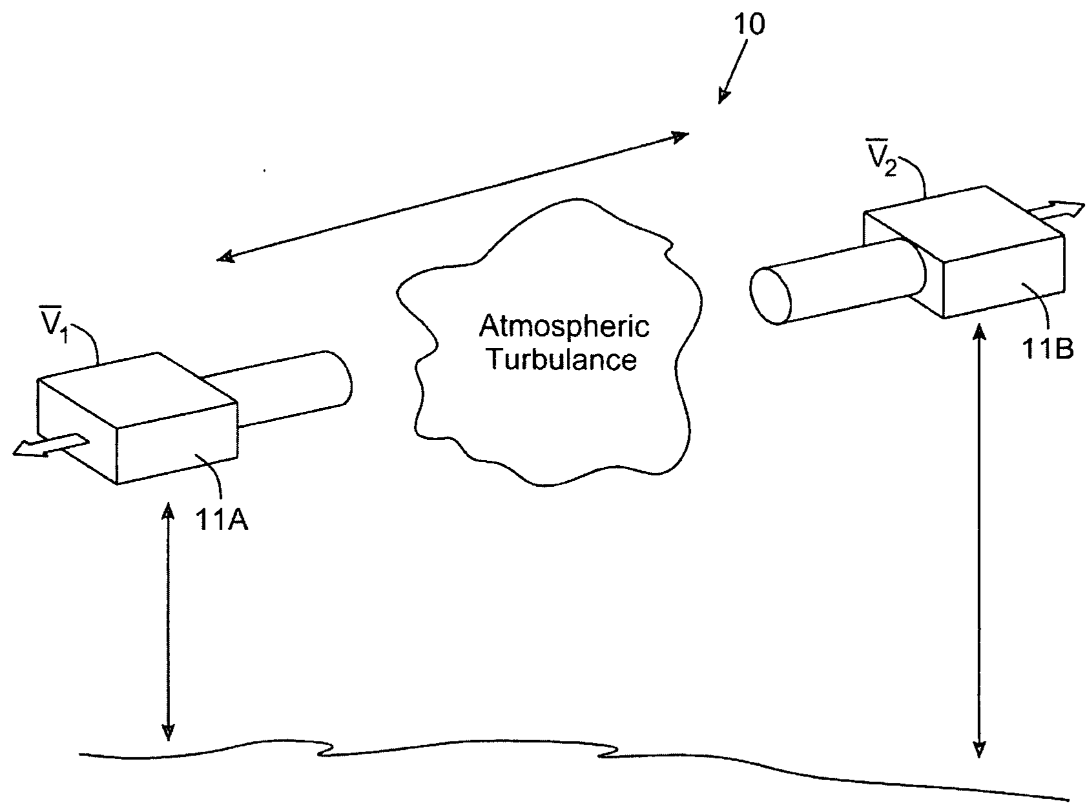


FIG. 7A

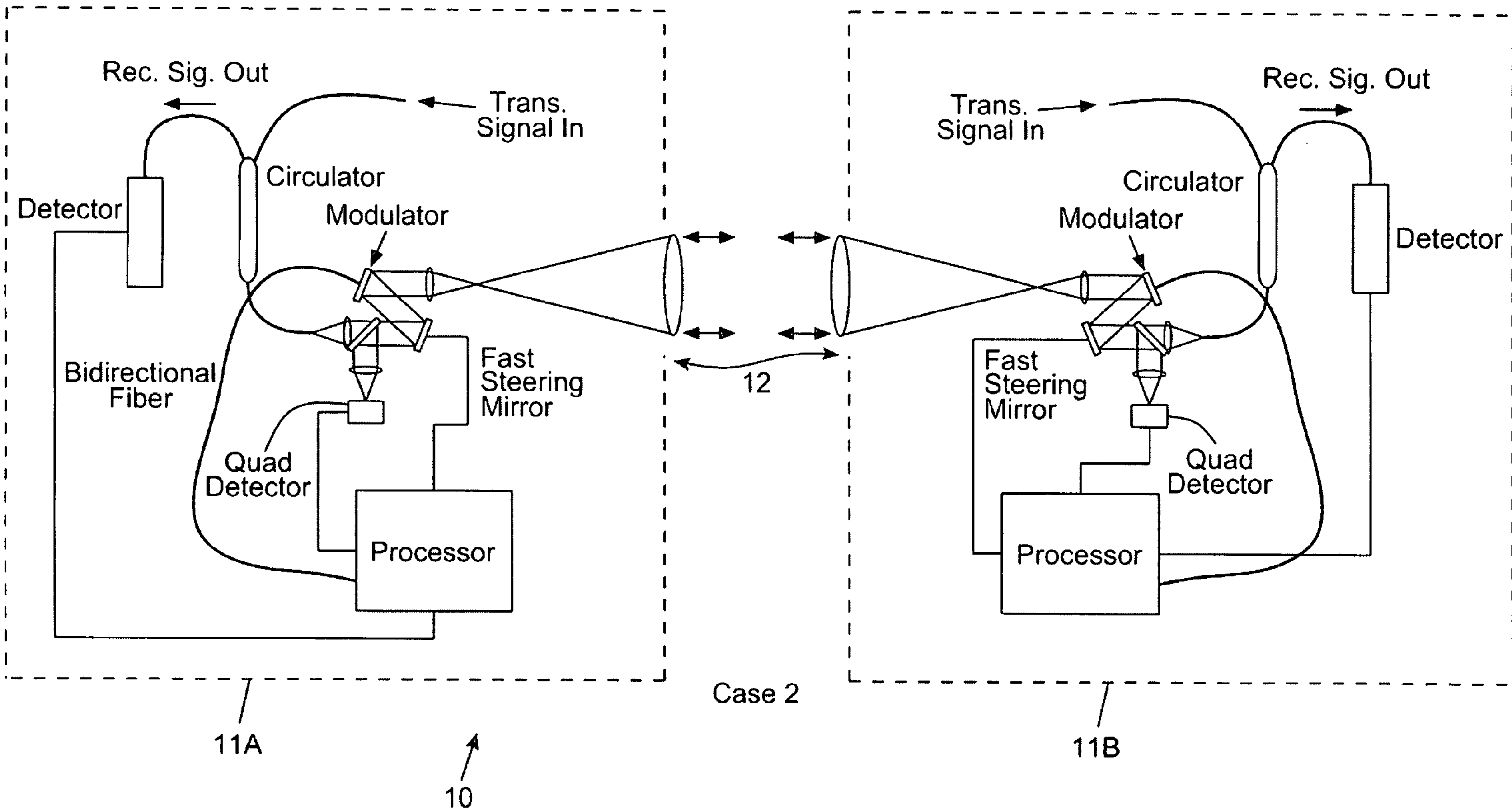

Rec. Sig. Out
Trans.
Signal In
Circulator
Detector
Modulator
Bidirectional
Fiber
Fast
Steering
Mirror
Quad
Detector
Processor
12
Trans.
Signal In
Rec. Sig. Out
Circulator
Modulator
Detector
Fast
Steering
Mirror
Quad
Detector
Processor
Case 2
11A
10
11B

FIG. 7B

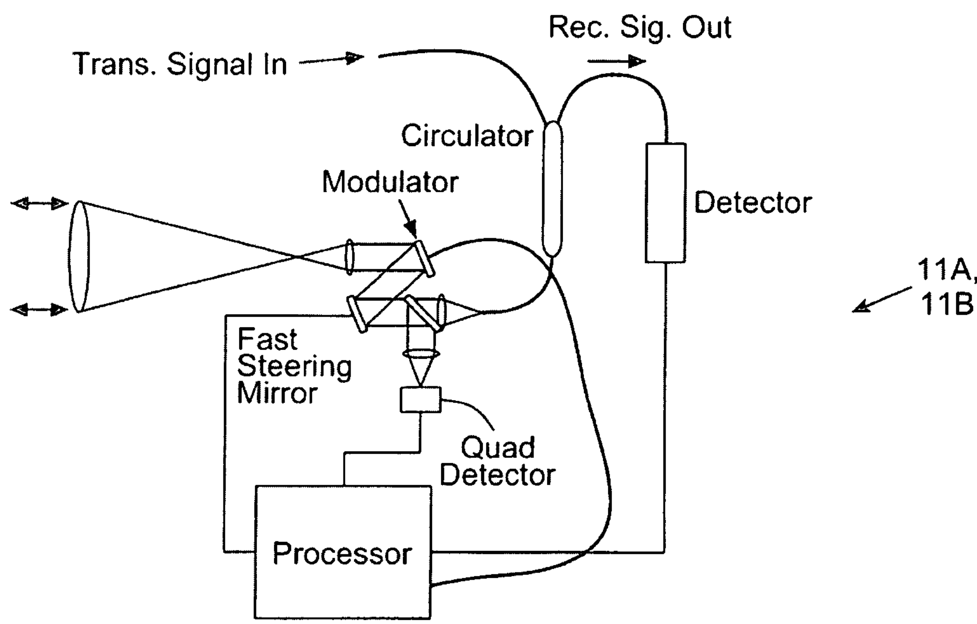

Trans. Signal In
Rec. Sig. Out
Circulator
Modulator
Detector
11A,
11B
Fast
Steering
Mirror
Quad
Detector
Processor

FIG. 7C

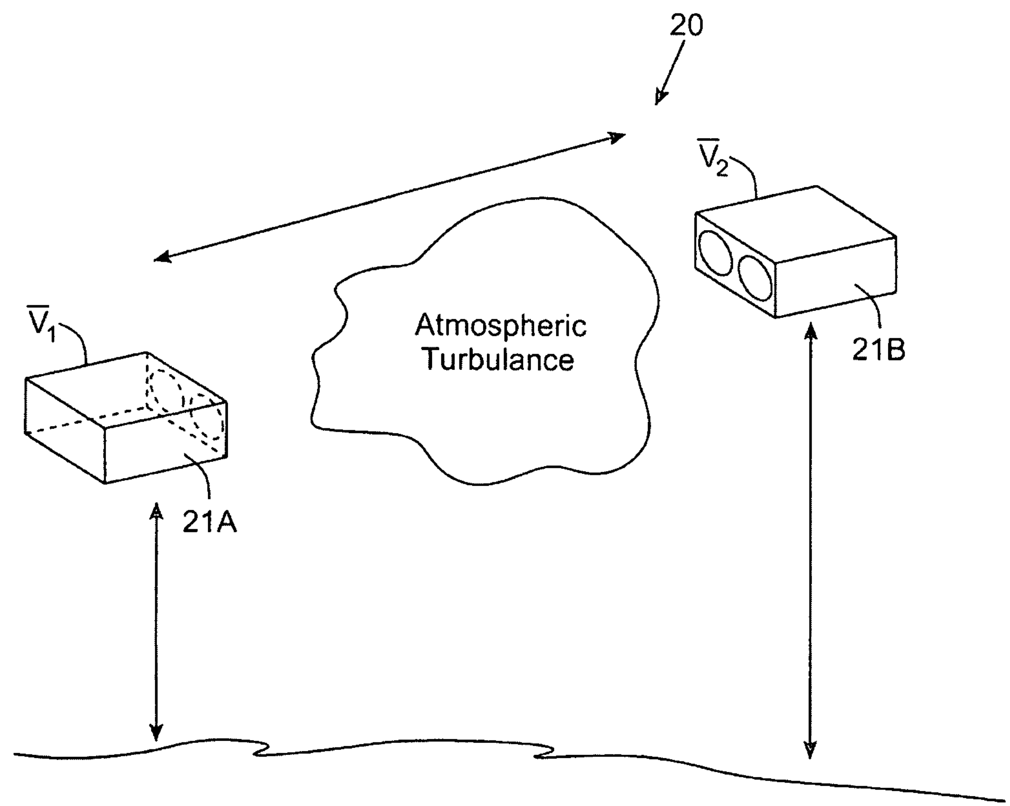


FIG. 8A

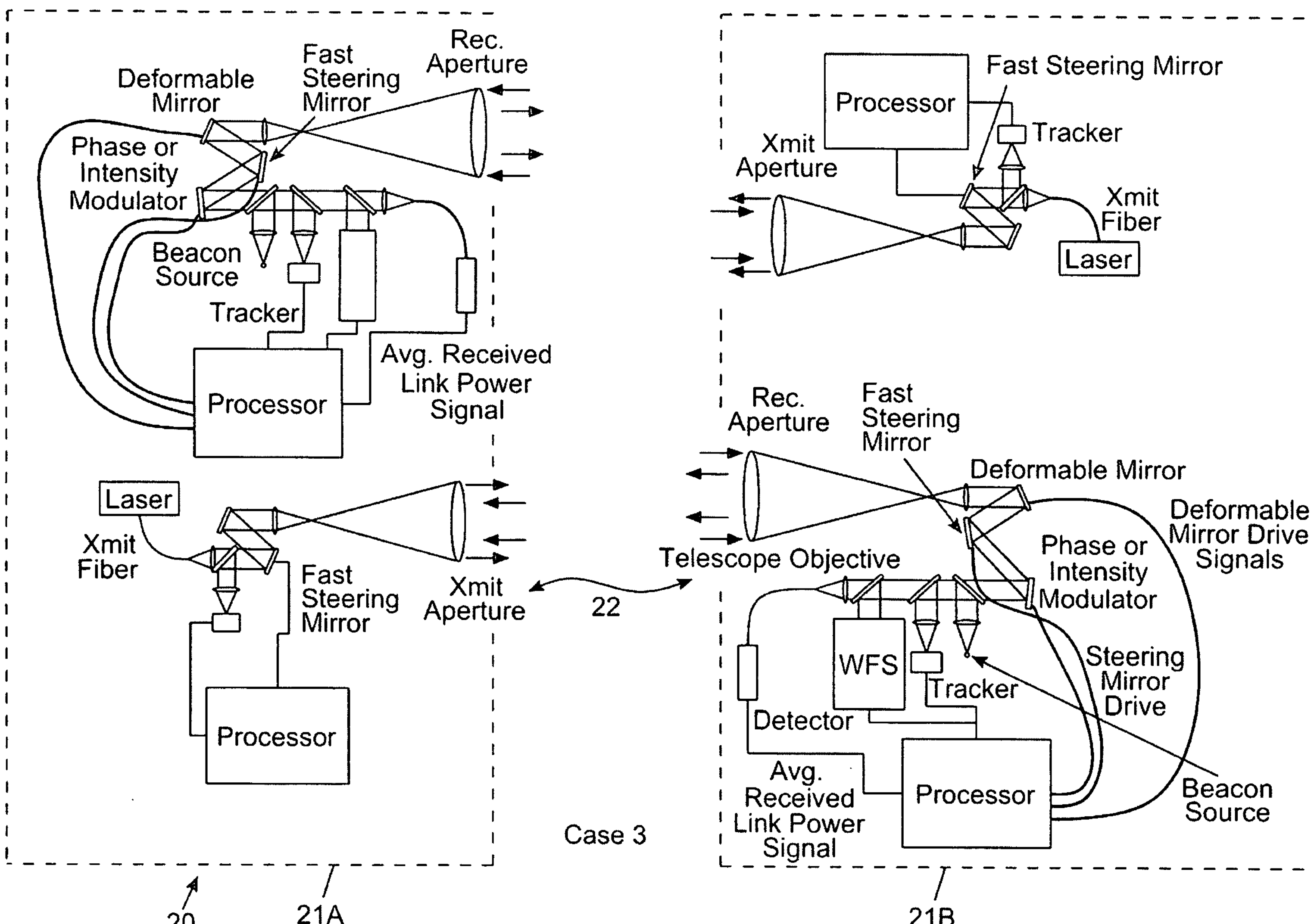
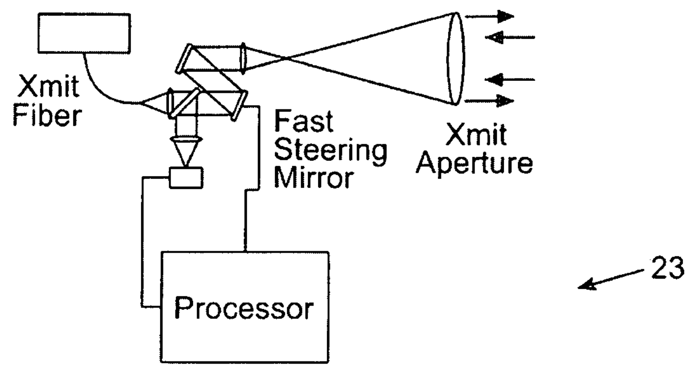
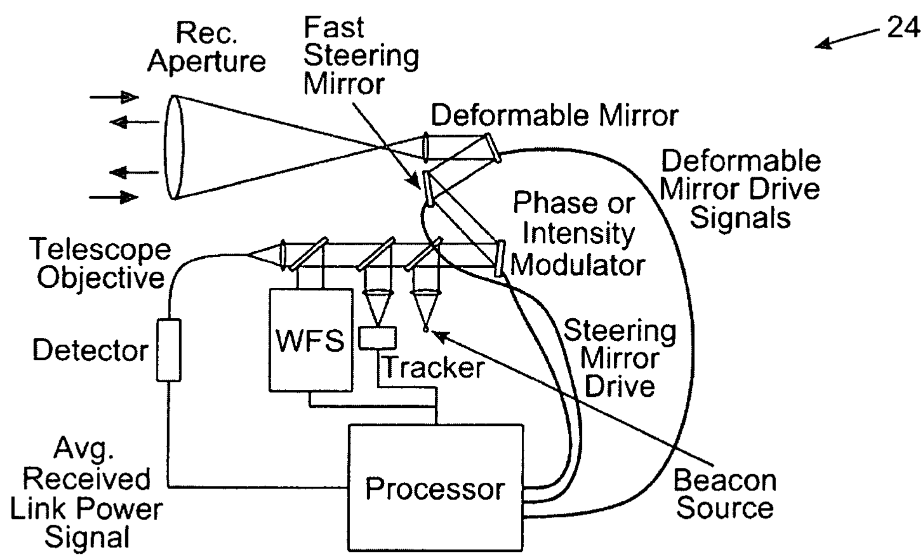

Deformable Mirror
Fast Steering Mirror
Rec. Aperture
Phase or Intensity Modulator
Beacon Source
Tracker
Avg. Received Link Power Signal
Processor
Laser
Xmit Fiber
Fast Steering Mirror
Xmit Aperture
Processor
22
Case 3
20
21A
Processor
Fast Steering Mirror
Tracker
Xmit Aperture
Xmit Fiber
Laser
Rec. Aperture
Fast Steering Mirror
Deformable Mirror
Deformable Mirror Drive Signals
Telescope Objective
Phase or Intensity Modulator
WFS
Steering Mirror Drive
Tracker
Detector
Avg. Received Link Power Signal
Processor
Beacon Source
21B

FIG. 8B



Xmit
Fiber
Fast
Steering
Mirror
Xmit
Aperture
Processor
23

FIG. 8C



24
Rec.
Aperture
Fast
Steering
Mirror
Deformable Mirror
Deformable
Mirror Drive
Signals
Phase or
Intensity
Modulator
Telescope
Objective
Detector
WFS
Tracker
Steering
Mirror
Drive
Avg.
Received
Link Power
Signal
Processor
Beacon
Source

FIG. 8D

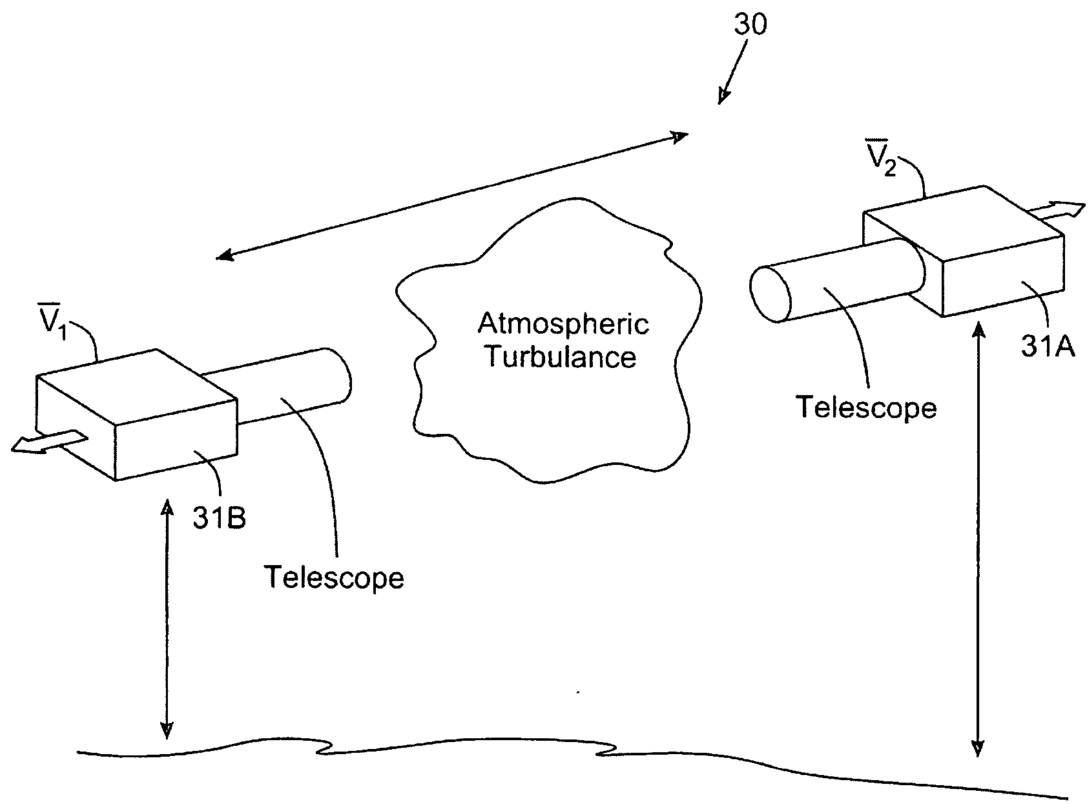
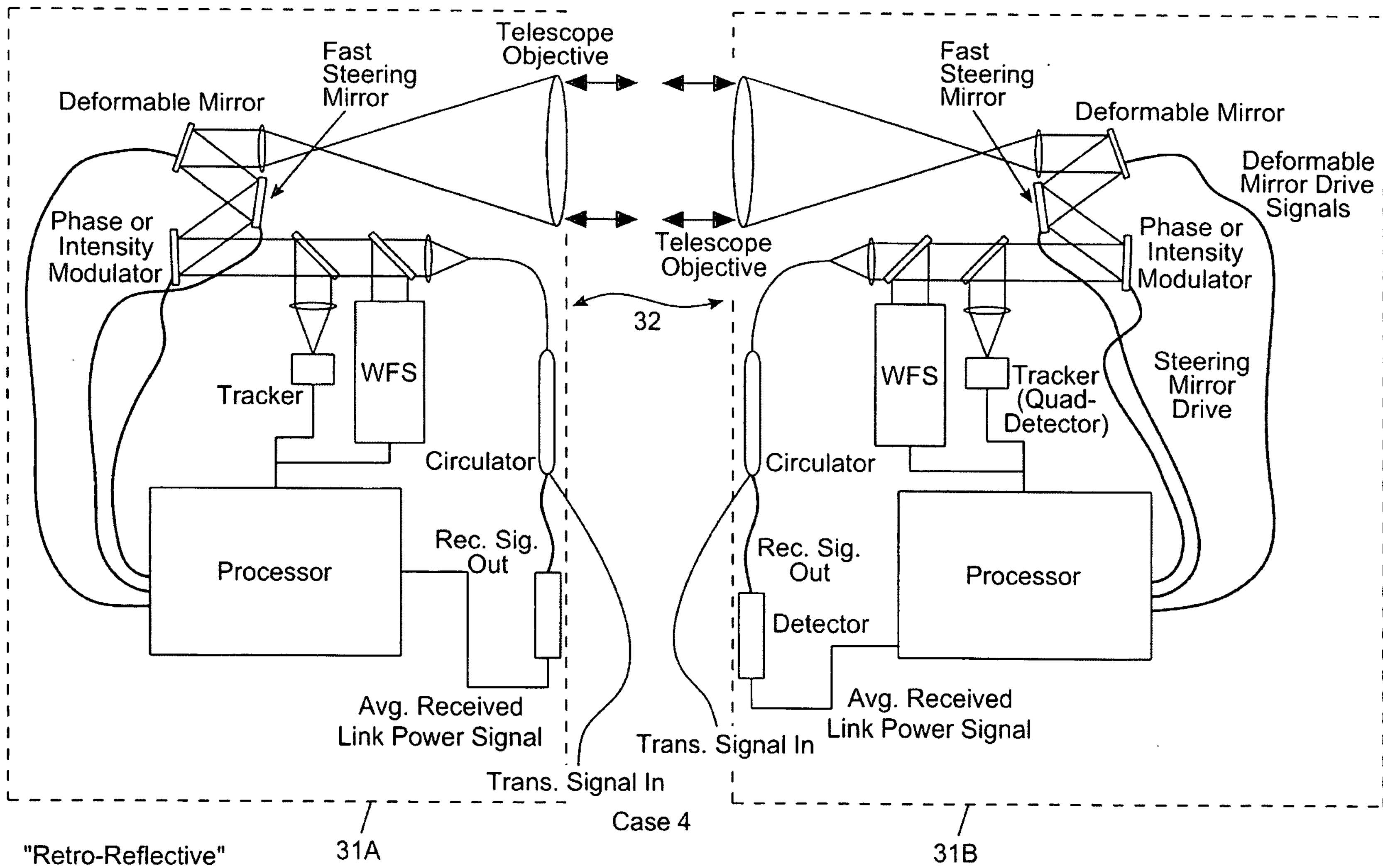

30
$\overline{V}_2$
31A
Telescope
Atmospheric
Turbulance
$\overline{V}_1$
31B
Telescope

FIG. 9A



Deformable Mirror
Fast Steering Mirror
Telescope Objective
Phase or Intensity Modulator
Tracker
WFS
Circulator
Processor
Rec. Sig. Out
Avg. Received Link Power Signal
Trans. Signal In
32
Telescope Objective
Fast Steering Mirror
Deformable Mirror
Deformable Mirror Drive Signals
Phase or Intensity Modulator
Steering Mirror Drive
WFS
Tracker (Quad-Detector)
Circulator
Rec. Sig. Out
Detector
Processor
Avg. Received Link Power Signal
Trans. Signal In
Case 4
"Retro-Reflective"
31A
31B

FIG. 9B

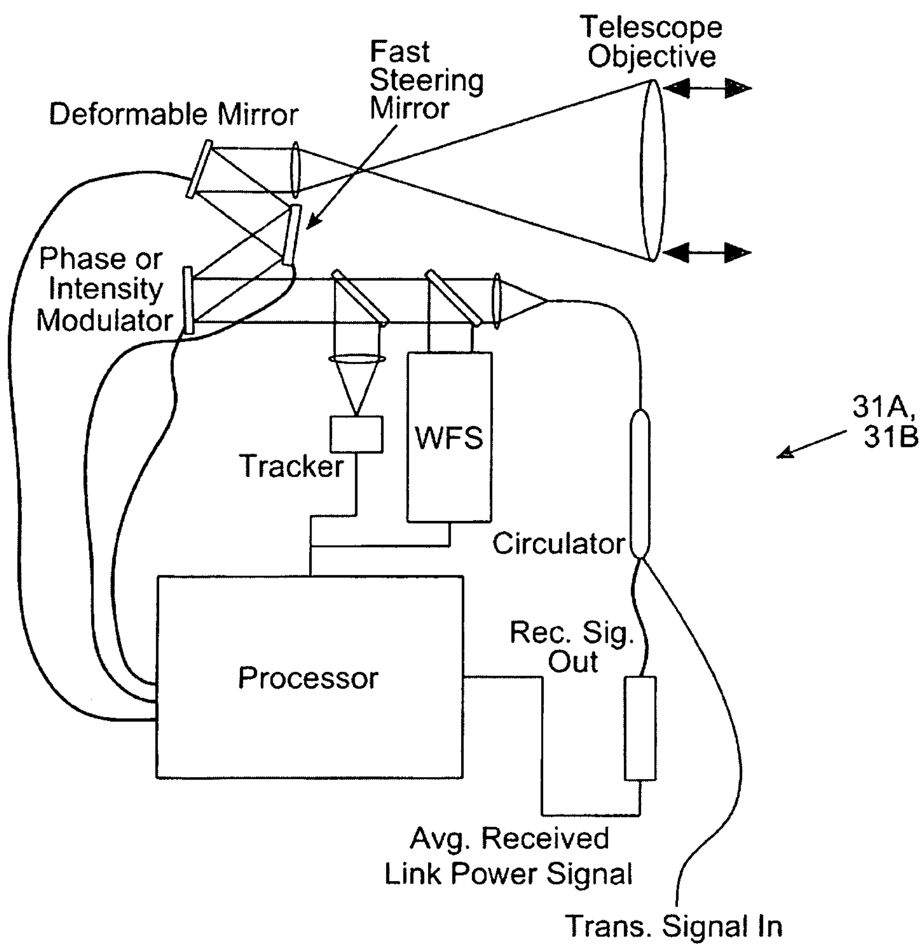
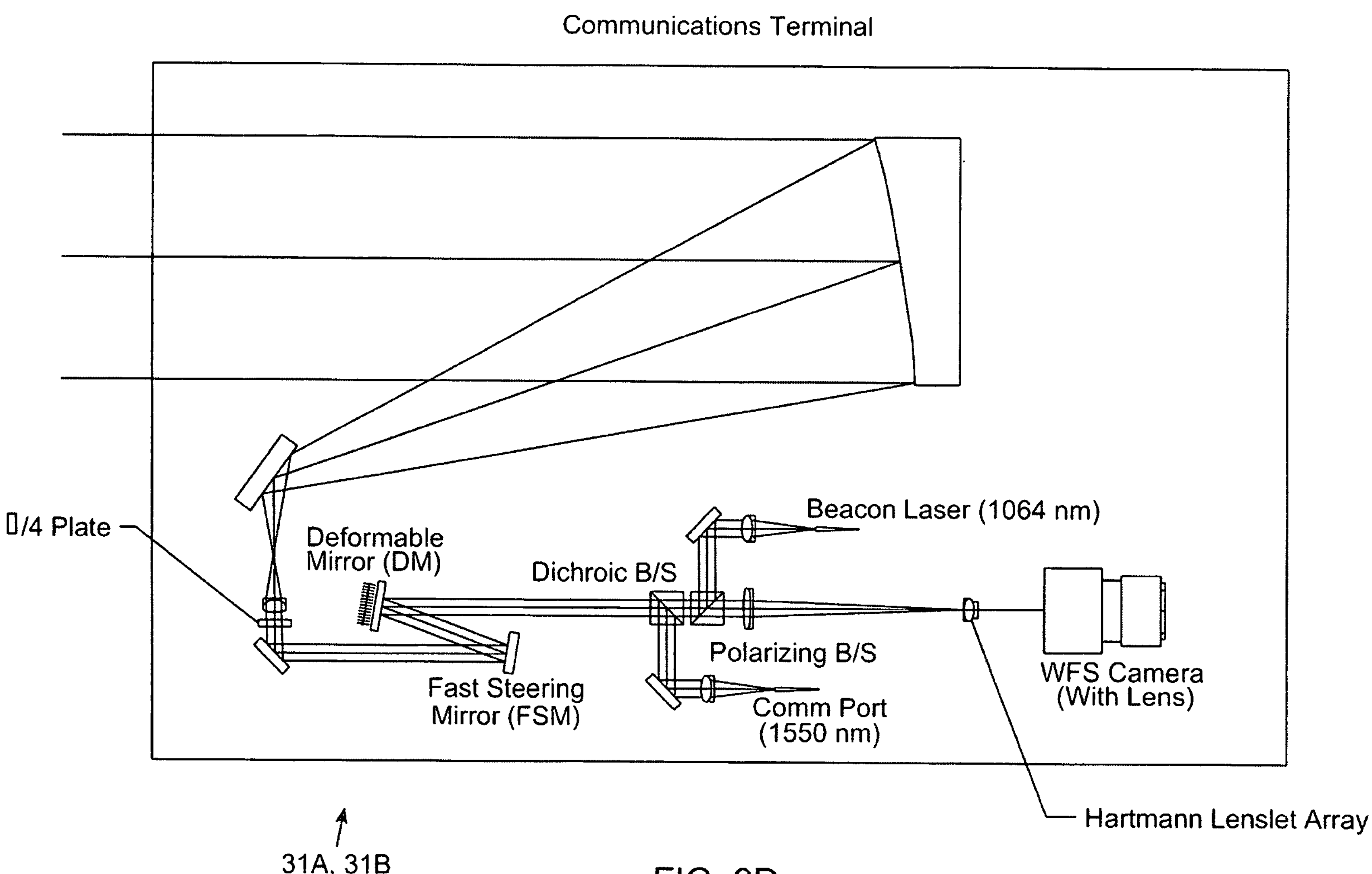
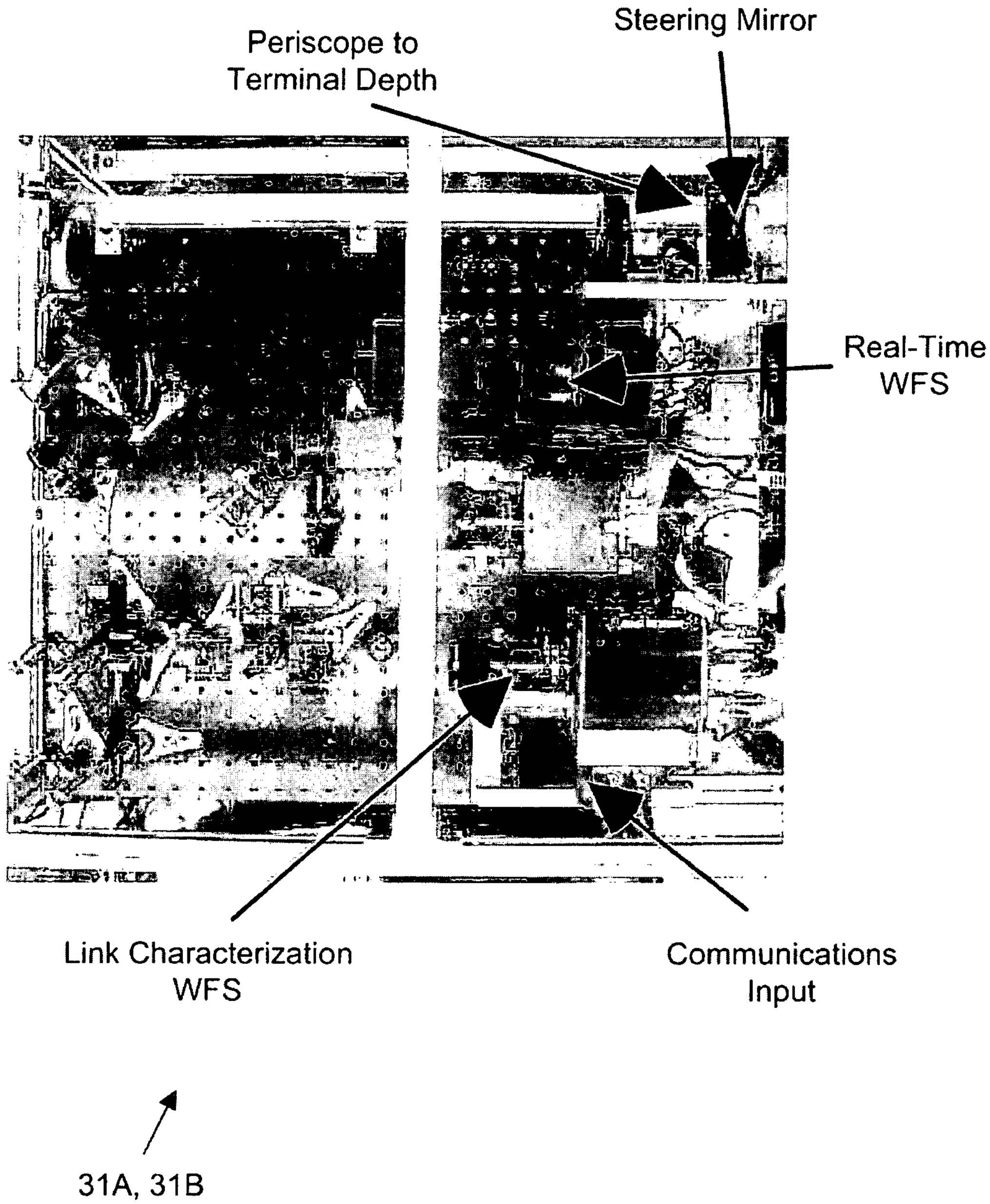

Telescope
Objective
Fast
Steering
Mirror
Deformable Mirror
Phase or
Intensity
Modulator
WFS
Tracker
31A,
31B
Circulator
Processor
Rec. Sig.
Out
Avg. Received
Link Power Signal
Trans. Signal In

FIG. 9C



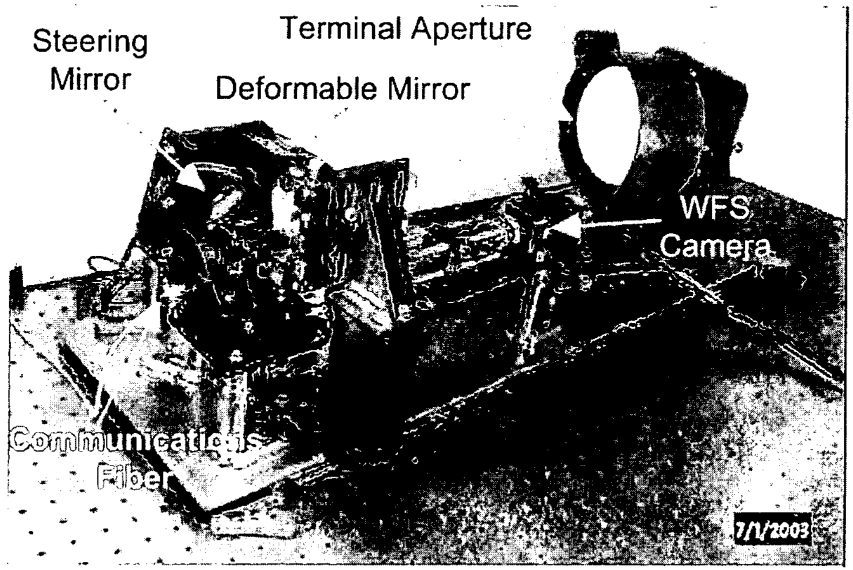
Communications Terminal
□/4 Plate
Deformable
Mirror (DM)
Dichroic B/S
Beacon Laser (1064 nm)
Polarizing B/S
Fast Steering
Mirror (FSM)
Comm Port
(1550 nm)
WFS Camera
(With Lens)
Hartmann Lenslet Array
31A, 31B

FIG. 9D



Periscope to
Terminal Depth
Steering Mirror
Real-Time
WFS
Link Characterization
WFS
Communications
Input
31A, 31B

FIG. 9E



31A, 31B

Compact laser communications terminal with 15cm aperture. This terminal has both a fast steering mirror and deformable mirror for atmospheric compensation. This terminal is set up as either a transmitter or receiver, with a separate fiber port for a tracking and AO beacon laser source (hidden by the DM mount).

These are both laser comm. terminals with traditional adaptive optics. A terminal with fade prevention would look similar. Note that these use reflecting telescopes (the one on the top has an 8 inch Schmidt Cassegrain telescope on the other side of the optical breadboard. In the schematic drawings a refracting telescope is shown for simplicity. Either can be used in practice.

FIG. 9F

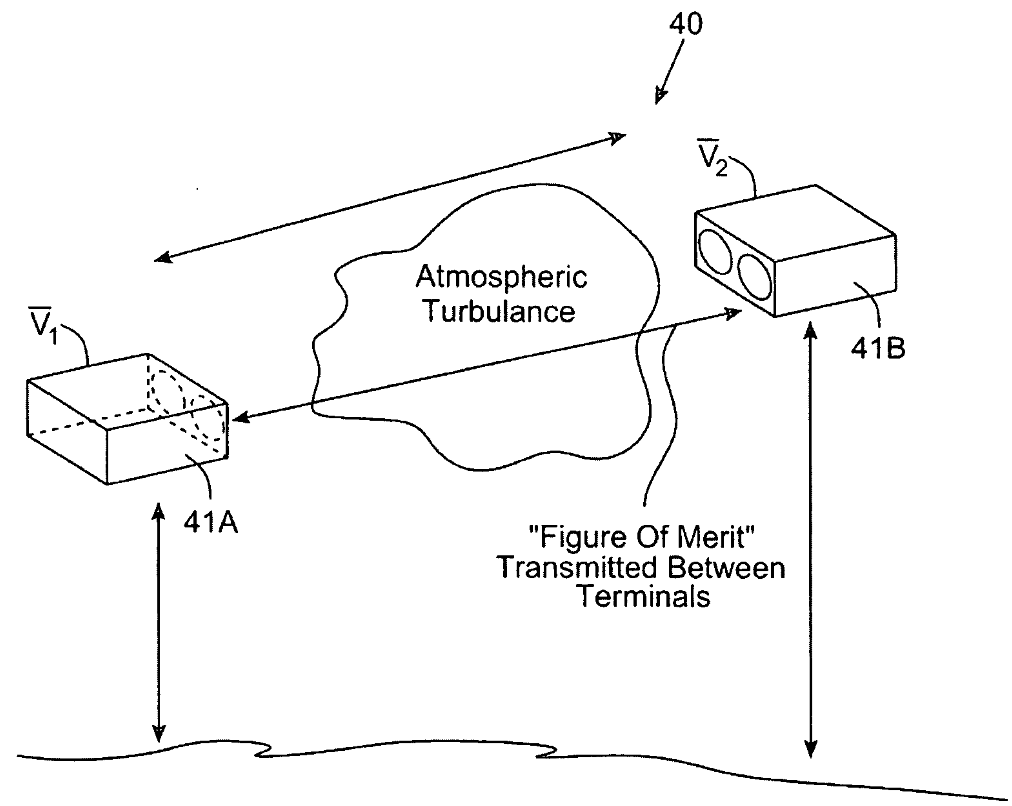

40
$\overline{V}_2$
$\overline{V}_1$
Atmospheric Turbulance
41B
41A
"Figure Of Merit" Transmitted Between Terminals

FIG. 10A

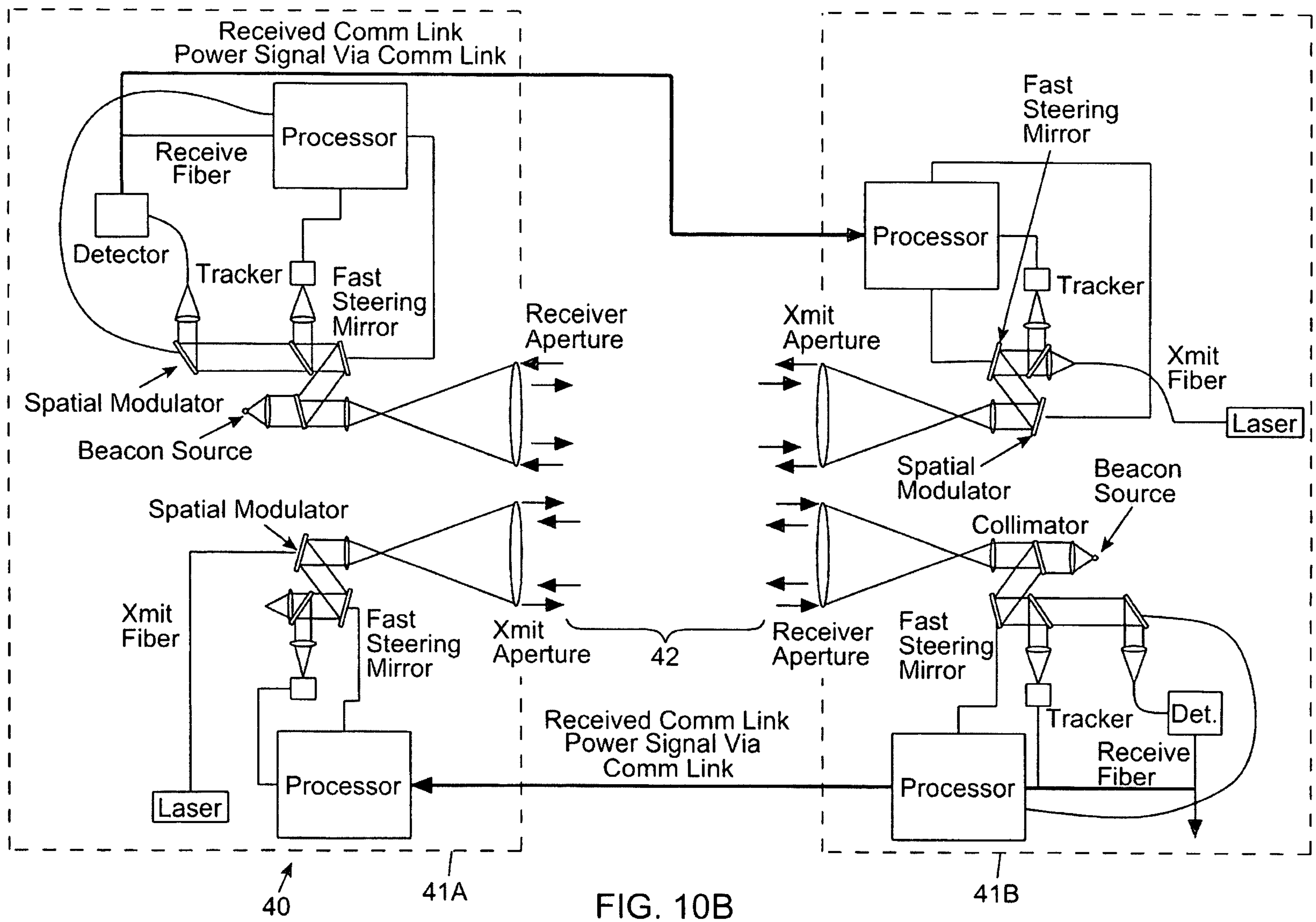

Received Comm Link
Power Signal Via Comm Link
Processor
Receive
Fiber
Detector
Tracker
Fast
Steering
Mirror
Spatial Modulator
Beacon Source
Receiver
Aperture
Spatial Modulator
Xmit
Fiber
Fast
Steering
Mirror
Laser
Processor
Xmit
Aperture
42
Fast
Steering
Mirror
Processor
Tracker
Xmit
Aperture
Xmit
Fiber
Laser
Spatial
Modulator
Beacon
Source
Collimator
Receiver
Aperture
Fast
Steering
Mirror
Tracker
Det.
Receive
Fiber
Received Comm Link
Power Signal Via
Comm Link
Processor
40
41A
41B

FIG. 10B